COAL ECONOMY.

FRED. CHAS. DANVERS.

ON COAL

WITH REFERENCE TO ITS

SCREENING, TRANSPORT,

&c.

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" I am really concerned for the honour of Coal; it is an interesting subject, " especially in India; and, as very little relative to what is herein recorded has " been said about it hitherto, that I know of, I reckon the subject my own, " and therefore I wish to be its faithful historian."—*Paraphrased from a " Natural History of the Mineral Kingdom*, 1789."

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PREFACE.

The importance of economising our Coal resources has only been forcibly recognised within the past few years, and the voluminous Report by the Coal Commission recently published sets the whole question of Coal Economy before the public in a more complete and comprehensive manner than had previously been anywhere attempted. That Report, however, deals principally with waste in working and waste in consumption, so far as the direct question of *economy* is concerned, but it does not directly deal with the many considerations by which Coal is affected between the Colliery and the place of its ultimate destination, such as " Screening," " Transport by Railway and Canal," " Storeage," Shipment," &c., all of which are most important subjects in connection with the great question of Coal Economy. With the exception of the last-named, these subjects do not appear ever to have received the serious consideration they deserve of those who have before taken up the investigation of questions connected with our Coal supplies, and the present Work has therefore been prepared with the view of affording information concerning them.

This treatise on "Coal Economy" was commenced with the view of forming the subject of a Report to the Indian

Government. It has now been approved and ordered to be printed by the Secretary of State for India in Council, for circulation in India; but the importance of the subjects dealt with appears also to warrant its publication in this country, and, from the opinions expressed by those to whom the manuscript was submitted prior to publication, to justify the expectation that the information collected would form a not altogether invaluable addition to existing publications more or less relating to "Coal Economy."

F. C. D.

CHAPTER I.

INTRODUCTORY.

Importance of the Subject—Fuel for Indian Railways—Manufacture of Iron in India—Economy of Fuel—No published information existing on the Subject—Determination to make investigations into it—Time limited, and enquiries therefore confined to South Wales and Northumberland—The Colliery—Methods of Mining not investigated—Treatment of Coal at the Pit's mouth—Amount of small Coal left below, and brought to bank—Loss in small Coal made after reaching the surface—Screening—Softness of Indian Coal—Utilization of small Coal—The Heapstead—Collieries visited—Railways on which Coal is carried—Mineral Railways—Main Lines—Unloading of Trucks—Depôts for Coals—Canal carriage—Delivery into barges—Loading and unloading of vessels—Ports visited—General Observations.

HAVING for some years past taken particular interest in the development of the Indian Coalfields, that subject appears to me to have attained considerably increased importance since the determination was made by Government to undertake the construction of a system of State Railways throughout India. As the length of open line increases in India so must the question of fuel supply for the locomotives, and other services in connection with railway working, increase in importance. If the manufacture of iron be ever introduced into India to any extent, and if, as it is to be hoped may be the case, provision be made for re-rolling the railway bars in India, as they become worn out, then it is clear that the continuous increase in the demand for fuel, for the above purposes alone, must in future years progress at a very rapid rate, to say nothing of the demand which will most probably increase in a similar ratio for other purposes of commerce and manufacture. It does not appear probable that any amount of forest conservancy will ever suffice to secure a supply of wood fuel that will render India independent of her coal supplies. There exists no reason for supposing that in this respect India will form any exception to other

countries where coal has been found, for it has been the invariable rule that with an increase of serviceable coal supply the demand for fuel has so extended that the use of wood alone becomes impossible. It is stated in Mr. Juland Danvers' Report on Railways in India for 1870–71, that "A regular system has been organised in the Madras Presidency for obtaining an adequate supply of wood fuel for railway purposes. It has been estimated that *nearly one hundred square miles* will be required to meet the demand, &c." This alone will give some idea of the extent of country that would have to be devoted to the purposes of growing fuel for railways, and which might probably be more profitably devoted to the growth of grain, if the demand should increase in any rapid proportion; for it must be borne in mind that an increase of traffic on a railway causes an increase in the consumption of fuel, and that for every additional ton of merchandise carried so much extra fuel is expended. The railways of the United Kingdom now run over 12,803 miles, and the quantity of coal used by them, for locomotives and for other railway purposes, amounts to 2,027,500 tons in the course of the year.* The length of railway now open in India is a little in excess of 5,000 miles, but the traffic being less, a proportional amount of fuel to length of line is not now required; the number of train miles run being 139,647,569,† and 14,396,790,‡ in England and India respectively.

The beds of coal worked in India having, until quite recently, been confined to the Ranigunj district, the use of Indian coal for railway purposes has necessarily been very limited, but the rapid increase in the quantity raised is somewhat remarkable; "with some fluctuations, the amount of coal raised in India has, during the eleven years, from 1858 to 1868 inclusive, steadily increased from 61½ lakhs of maunds in 1858 to 127¼ lakhs of maunds in 1868. In other words, the quantity has considerably more than doubled during the lapse of ten years. If we go back still further, we find that in 1850 the total quantity sent away from the Ranigunj field was

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* "Report of Coal Commissioners, 1871," vol. 3, p. 204.

† Printed Parliamentary Paper (c. 229) of 1870.

‡ "Report on Indian Railways, 1870-71."

22 lakhs of maunds; while in 1868 this out-turn had grown to 126 lakhs, or nearly six times the amount. Few industries can point to such an extension within the same number of years."* With the development of the coalfields recently discovered in the Central Provinces, it may well be anticipated that the quantity of coal raised in India in future years will continue, for some time to come, to increase very rapidly. So far as railways are concerned, it is unquestionable that the demand for fuel must annually increase in India; and it may not be altogether out of place here to remark, that by the use of a rotary puddling furnace recently introduced in America, the principal difficulties in the way of iron manufacture in India may be successfully overcome.† Should my anticipations in this respect be fulfilled, there will at once be opened up a new industry in India, for which a very large supply of fuel will be required.

vons Professor ~~Jervous~~‡ has pointed out that, although, according to the mechanical theory of heat, the work done by coal in a good engine of the present day does not exceed about one-sixth part of what the coal is capable of doing, any improvement for the purpose of economising its power is not likely to be accompanied by a corresponding reduction in consumption. "It is wholly a confusion of ideas," he says, "to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth." If a diminished demand for coal then, is not to be looked for as a consequence of the introduction of improved and more economical means of using it, the same amount of fuel may be made to go further by the introduction of improvements in the means of getting it in the first instance, and in the haulage

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* "Coal Commissioners Report, 1871," vol. III., p. 233.

† I refer to Danks's Patent Rotary Furnace, a paper on which was read at a recent meeting of the Iron and Steel Institute at Dudley, at which I was present. So favourable an opinion was entertained by the members of the Institute, of the value of this invention, that they sent out a Commission to America to make further enquiries concerning it, who have since reported most fully in its favour, and puddling furnaces on Danks' principle are now being put up by several leading iron masters in England.

‡ "The Coal Question," W. S. Jevons ~~Jervous~~, 1866, p. 123.

and transport of it in the second; or, in other words, by the avoidance of waste.

Although an immense amount of information exists relative to the getting of coal, and a few papers have been published relative to the shipment of coal, I have been able to discover *no published books or papers whatever* that would throw any light upon the important questions of the "screening," "transport," "haulage," and "storeage" of coals. Being impressed with the conviction that information on these points would be of great use for general information, but more particularly for India, where coal mining may be said to be yet in its infancy, I resolved last year to investigate various questions embraced under the several headings abovementioned. As the time at my disposal was, however, not sufficient to admit of my visiting all the principal coal fields in England, I determined, after seeking advice on the subject from several competent authorities, to limit my present investigations to the coalfields in South Wales, and about Newcastle, as I was assured that, after visiting those districts, I should probably have seen all the best and newest appliances in use in England. Thus, whilst my enquiries may be said to have been, to a certain extent, only limited in the extent over which they have been conducted, so far as regards questions concerning the delivery of coal from the mouth of the pit, I have reason to believe that I should have gained very few additional items of information had I extended my investigations to the Lancashire and Midland coal districts. By reference to the Coal Commissioners Report, Vol. I. Page ix., it will be seen that the South Wales coal-bed is the largest, and, with the exception of the Midland coalbed, which ranks second in importance, the Northumberland and Durham coal-field is the next largest. For the special object of my enquiries, however, I was advised to visit the Northumberland rather than the Midland district.

My investigations at the colliery were with reference to the treatment the coal receives from the moment it emerges from the pit's mouth; more particularly with reference to the mode of screening and delivery into wagons; but I have purposely omitted any allusion to the working of the coal underground, as that is a subject

which has repeatedly, and most fully, been treated of by others more acquainted with the subject, and therefore better qualified for the purpose than myself. The amount of small coal made in working, and the quantities of it left below and brought to bank respectively, have, however, received my particular attention, as well as the extent of deterioration which the coal undergoes during the several processes through which it passes, prior to arriving at its destination for consumption. My enquiries on this latter question may, to a certain extent, be considered as an extension of the investigations undertaken by Committee C, appointed by the Coal Commission to report on "waste in working." A great deal of most valuable information is contained in the evidence given before that Committee,* showing an amount of waste which is equivalent in reality to a great national loss, for under favourable systems of working the loss is estimated at about ten per cent., while in a very large number of instances the ordinary waste and loss amounts to forty per cent.† My recent inquiries not only enable me fully to corroborate the above statement, but I am prepared to show that the loss in many instances is considerably greater than is there stated. The foregoing refers, however, only to the loss in working, but after being raised, coal undergoes a further continuous depreciation in every stage through which it is passed until it finally arrives at the point of its ultimate destination. Thus, waste of coal through breakage is occasioned by delivery down a shoot, and still more so by the process of screening, for, as will be found in a subsequent portion of this report, the more coal is screened, the more small is got out of it by the breakage of the coal in passing over the screen, and it is unquestionably a fact, as was remarked to me during my visit to Swansea, "if you only had a screen long enough all the coal would pass through, and none would ever reach the bottom of it." I believe the practice of screening, to the extent to which it is adopted in South Wales, is particularly destructive, and it is a somewhat curious fact that whereas the steam coal of South Wales has to undergo numerous screenings, that of the

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* "Coal Commissioners' Report, 1871," vol. II., p. 313 to 412.

† "Coal Commissioners' Report, 1871," vol. I., p. 9.

Newcastle district, which would not suffer so much from the process, is, as a rule, scarcely screened at all. This question of screening becomes therefore an important one for India, where much of the coal is of a very soft character, and it is one to which I have consequently devoted a considerable amount of attention. In addition to the loss made by screening, the shaking of the coal in railway wagons during its conveyance from the colliery, causes further breakage, and its delivery from the wagon, either into ships or into depôt, is, even when the greatest possible care is exercised, and the best known appliances and machinery employed, invariably attended by a still further depreciation in the amount of large coal ultimately available for use as "round coal." Again, with very soft coal, such as that obtained from the Mayo Pit, at Chanda, exposure to the atmosphere causes it to disintegrate to a certain extent, occasioning thereby a still further loss of serviceable coal. It will therefore be seen that, even with the greatest care, a very large amount of coal is depreciated, if not actually destroyed, in addition to the loss made in working. My attention has, for some time past, been particularly given to the question of how to utilise this small coal, which is now too often wasted. In Northumberland I have seen railway lines ballasted with coal, and some small railway embankments constructed apparently, entirely with small coal, whilst at almost every pit's mouth are to be seen heaps containing thousands of tons of what might be converted into valuable fuel. In Chapter VI. this question is dealt with more fully, and I shall, therefore, say no more on it now.

The arrangement of the "heapstead," or "pit bank," as the head works of a colliery are technically called, appeared also to be deserving of a little consideration and attention, as the economical working of a colliery pit must depend, in a measure, upon all the appliances used in connection with it. In this respect I have found various practices prevailing in different parts, which will be more fully described in another chapter.

The collieries at which I have gathered information especially for the purposes of this paper are, in South Wales, the Powell's Duffryn, the Nixon's Duffryn, and the Nixon's Navigation Collieries at Mountain Ash, and Blamgwawr Colliery, belonging to Messrs. David Davis

and Sons, at Aberdare. In the northern district, the Hilda Colliery, at South Shields; Ryhope Colliery, at Sunderland; Cambois Colliery, near Blyth; and the Barrington and Bedlington Collieries near Morpeth.

With reference to railways and the haulage of coal, my investigations have reference to the permanent way, weight of rails, speed of trains, locomotives, rolling stock, maximum weight of trains, and rates charged for carriage. Not the least important amongst my enquiries has been the question of break of gauge, as that is one which will shortly arise in India, when narrow gauge lines shall have been constructed to connect the Central Provinces coalfields with the Great Indian Peninsular Railway. Fortunately there has been some experience on this point in England, for at one time, before the narrow gauge was laid down on the Great Western Railway between Wolverhampton and London, coals had to be transhipped at the former place from narrow into broad gauge wagons. I have taken great pains to collect all the information obtainable upon this head.

It may be said that, for coal traffic, two classes of railway exist, and the present paper would have been incomplete had my enquiries been limited only to one of them. There is, first, the mineral line, leading direct up to the several collieries, and carrying little else besides coal, and the great main lines of railway over which coal is conveyed from the mineral lines to the principal centres of industry along their respective routes. In the former case, the railway is laid out with special reference to its coal traffic, the conveyance of passengers being only a secondary consideration. To this class, it is presumed, the contemplated line from Chanda would most properly belong; and as, with the discovery of new coal fields, other lines of a similar character will be required, I have thought it of sufficient importance to make most minute enquiries into the construction and working of such lines in England. For this purpose I selected the Taff Vale Railway in South Wales, and the Blyth and Tyne Railway in Northumberland. The second class of railway to which I have referred, on which there is a large coal traffic, consists of those main lines which would correspond with the existing arterial lines in India, and their future probable extensions.

With these, wherever there is a large passenger traffic, the goods trains must of course give way to the passenger trains. Although the East India Railway is not unacquainted with coal traffic combined with passenger traffic, I have thought it desirable, with a view to render my present paper complete, to institute enquiries into the mineral working of our main lines of railway, and I have accordingly collected my information, under this heading, from the following railways, viz:—The Great Western, The North Western, The Midland, The Great Northern, The Great Eastern, and The North Eastern.

Immediately connected with the latter class of railways is the question of unloading railway trucks, and depositing coal into the great central depôts for town consumption. Very great improvements have of late years been made in the arrangements of urban depôts, and some very extensive buildings have quite recently been erected in London for the purpose, in which are embodied all the improvements that experience has shown hitherto, can be adopted for the purposes of economy and expedition. The principal coal depôts about London are those at Hackney, Holloway, Camden Town, Kentish Town, Caledonian Road, Agar Town, Shoreditch, Elephant and Castle, and Walworth Road, particulars of which will be found in the following pages. As a rule, these depôts are employed solely for the storeage of coal used for domestic and other town purposes, steam coal for vessels being usually emptied into barges in London, and so conveyed by means of canals to the Thames, excepting when such steamers happen to be in dock, and facilities exist for running the coal trucks direct on to the quay, when special machinery is employed, which will be separately noticed presently.

During the process of delivering coal into depôt, a considerable amount of "small" is separated from it, showing that since leaving the pit a further process of deterioration has been going on, and, although in the vicinity of large towns there is plenty of demand for small coal for brick burning and other manufacturing purposes, the price that it commands is considerably less than what can be obtained for round coal, and the loss of money to the coal merchant on the former article has, of course, to be made up by an increase of charge on the latter. Thus, the

public have to pay, in the long run, for the breakage of coal in this, as in all other stages through which it has to pass; and any economy that can be obtained in this respect, by the introduction of improved means of transport, or by the application of better mechanical appliances for the loading and unloading of coal into wagons, barges, ships, or depôts, may fairly be regarded as so much addition to the available mineral fuel wealth of the country. If the above proposition may be considered a fair one with respect to this country, where we have coals of every degree of hardness, how much more will it apply to India, whose coal resources, as at present discovered and worked, produce a fuel of a very tender and friable nature?

Although canal carriage for coal has now been almost entirely superseded by railways, there nevertheless are certain circumstances under which the latter cannot convey coal to its ultimate destination, when barges can be employed for the purpose, and taking into consideration the existence of numerous canals in India, leading to districts where railways will probably not find their way for many years to come, but where coal, if obtainable, would be eagerly sought after, and that others, such as the circular canals about Calcutta, may be economically employed for the distribution of coal, I have thought it desirable to collect such information as was available relative to the loading and unloading of barges with coal. With very few exceptions, barges for coal traffic are hardly to be seen in the colliery districts which I have recently visited, but a not inconsiderable trade is carried on, in this way, in and about London.

The only other question to which I have given attention, for the purposes of this paper, is the loading and unloading of colliery vessels, and the filling of the bunkers of steamers with coal. So far as the loading of vessels with coals for transport is concerned, it is not probable that much will be required for India in that direction for many years to come, but the supply of fuel for steamers is a question already of every day importance, in India as much as anywhere else, where numberless river steamers, as well as ocean steamers, must constantly require to replenish their coal bunkers. It seemed, therefore, that the present paper would be incomplete

unless the subject were introduced, and full particulars given of the appliances in use for the purpose, at the different principal shipping ports in this country. It is true that information on this point has been already published to a certain extent, but nothing appears to have been written on the subject for some years past, and the improvements that have taken place in the machinery employed, within the last few years, have not so far as I have been able to ascertain, been recorded in such a manner as to make the information available to the public. The following remarks relative to this section of my paper are founded entirely upon personal observation on the spot, and wherever I may have found it desirable to borrow from the reports of others, the papers quoted from will be found mentioned in a foot note. The ports visited for the collection of information on this head were, in South Wales, Swansea, Cardiff and Newport, and in the North, Newcastle and the Tyne Docks.

In drawing up the following paper two points have been constantly borne in mind. Firstly, that in the absence of any previous publication treating on the several questions above mentioned, the information contained in the following pages will, it is hoped, be found to be of interest to all connected with the getting or sale of coal. The Coal Commissioners have, in Committee C, collected a vast amount of most valuable information on "Waste in Working," but their enquiries have been confined exclusively to underground working, whilst my investigations have commenced where theirs left off, and I have endeavoured to trace the amount of waste, or more properly speaking, the amount of small coal made during the subsequent stages which coal has to pass through before arriving at its ultimate destination, and this, it will be seen, is a question only second in importance to that which has been investigated in Committee C. In drawing attention to this most important subject, two considerations naturally suggest themselves, viz.: 1. How is this waste to be reduced? and 2. As under any circumstances, a certain amount of loss must arise from breakage, how can the small coal be best utilized?

There can be but little difficulty in replying to the former question. As the amount of breakage varies in the same coal, by the use of different appliances, so it

will only be by the introduction of the most approved machinery that any diminution will be effected in the amount of small coal made. The necessity for offering every possible encouragement for the introduction of improved machinery and appliances will at once be apparent when it is pointed out that assuming the difference in the value between round coal and small coal, at the pit's mouth, to be only 6*s.* 8*d.*,* the national loss occasioned in 1869 by every five per cent. of small coal made upon the total quantity retained for home consumption will have amounted to no less a sum than £1,617,775. As will be seen, however, in the following pages, the loss on this head considerably exceeds five per cent., but what the average might be for all the coal raised my enquiries have scarcely been sufficiently extensive to enable me to form any reliable estimate.

The utilization of small coal is a question entirely distinct from the former, although dependent upon it to a certain extent, and will be found treated on in a subsequent chapter.

Secondly. In taking up this question, the importance which the several points possess in respect to India appeared to me sufficient reason for undertaking my recent enquiries. With the opening up of new coal fields in India it is highly important that the best means and appliances should be introduced for working them economically in the first instance, with a view to avoid that waste which has already cost this country many millions sterling by the destruction and depreciation of a large proportion of her mineral wealth, and, by the neglect of possible and well known precautions, this waste is daily being continued in connection with many English collieries; there is also too much reason to fear that no satisfactory efforts will be made to put a stop to this great national loss until the subject is taken up in a decisive manner by Parliament.

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* Six and eightpence is a very low figure. I have found the difference in price, during my recent enquiries, vary from 6*s.* 6*d.* to as high as 8*s.* per ton, and at some places where there is no demand for small coal, it may almost be had for anything you like to offer.

CHAPTER II.

At the Colliery.

Small Coal made by "long wall," and "pillar and stall" systems of mining—Small Coal from Steam Coal and Bituminous Coal seams —The "separation" and "altogether Coal" principles—Amount of small Coal raised—Modes of paying the Collier—Analysis of Coal raised in one day from collieries on the two principles—Colliery Trams of various sizes—Advantages of Small Trams—Cages for raising the Trams—The Heapstead—The Pit-bank—The Weighbridge—Position of the Screens—Dimensions and forms of Screens vary in different districts—Distance between the Screen bars—Rocking Tables at head of Screens—Breakage of Coal on the Screen—Balanced Screens—They do not really save the Coal much, if at all —"Billy play-fair"—Register of small Coal raised—Considerations as to the cause of so much disintegration in Coal before it leaves the Colliery—Proper angle for Screens—Collection of small Coal where no "Billy-play-fair" is used—Illustrations of different kinds of Screen—Utilization of small Coal—Manufacture of Coke—Juke's Furnace—Burning Coal dust—Patent Fuel—Separation of small Coal into "nuts," "peas," and "duff"—Description of Screen for small Coal division—Value of different sized small Coal—Importance of economising Indian Coal—Duty of Indian Coal—Consumption in Locomotives on Indian lines.

The amount of small coal made in coal mining depends very much upon whether the "long wall" or the "pillar and stall" system is adopted. The evidence given before the Coal Commission shows that in the steam collieries forty per cent. is lost by the pillar and stall system, and fifteen per cent. by the long wall system.* This agrees very much with the experience of Mr. Alexander Bassett, of Cardiff, who has stated that, "on a careful investiga- "tion of this subject, it will be found in the steam coal "districts that upwards of forty per cent. of the actual "contents of the vein of coal worked is lost."† These observations, it should be remarked, refer to the South

* Vol. II., p. 326.

† "Transactions of The South Wales Institute of Engineers," vol. II., p. 182.

Wales district, where the recognised system for working coal is by pillar and stall. The small produced from steam coal always bears a large proportion to the whole amount worked.* "It is found to be comparatively "worthless, and does not pay for the expense of raising "it to the surface.† The small produced from the "bituminous veins is used for coking and other purposes, "therefore these seams of coal are frequently worked "through and through; consequently the proportion of "coal left behind in these collieries would not probably "average above one-half of that lost in the steam coal "districts."

According as the small coal is raised to the surface or not, the pit it is said to be worked on the "altogether coal," or on the "separation," principle. In the former case, sometimes as much as forty-five, and even fifty, per cent. of small coal passes through the screens at the pits' mouth, whilst in the latter, where, as in South Wales, the engagement is made with the collier that he shall only send up hand-picked coal, only from five to ten per cent. of small is screened out of what comes to bank. In some cases, the collier is not paid for any small that he sends up, whilst in others he is allowed one hundredweight out of every long ton (21 cwts.), and deducted for anything in excess of that amount. Where the "altogether coal" system is adopted, as it is to a great extent about Newcastle, the first screenings are generally again separated into what are called "nuts," which are the largest pieces taken out of the small, "peas" or "beans," those of intermediate size; and the remainder is called "duff" or "waste," and is generally thrown on one side. Taking the result of one day's working at an "altogether" pit near Sunderland, I found that the yield was 876½ chaldrons, which was made up in the following manner:—

404	chaldrons of	round coal	=46·1	per cent.	
183	,,	nuts	=20·9	,,	53·9 per cent.
154½	,,	beans	=17·6	,,	
135	,,	duff	=15·4	,,	

* "Transactions of The South Wales Institute of Engineers," vol. II., p. 182.

† A small proportion is used in the manufacture of Patent Fuel, but sufficient for that purpose is obtained from the screenings at the pit's mouth and at the docks.

In this case, supposing a ready market to exist for all the "nuts" and "beans," there remains a total loss equal to over fifteen per cent. of all that is brought up, irrespective of what is left below, which, if taken at fifteen per cent., shows a loss of upwards of thirty per cent. of the total seam of coal. It should be stated that the coal worked at this colliery is of an intermediate character, and is used both for steam and for domestic purposes. Taking another colliery, in the Newcastle district, whence steam coal is raised, and which is worked on the "separation" principle, I obtained the following results of one day's working:—Total quantity raised, 416 chaldrons,* of which

334	was round coal	=80·29 per cent.		
52	,, nuts	=12·5	,,	19·71 per cent.
16	,, beans	=3·85	,,	
14	,, duff	=3·36	,,	

In this instance the actual waste brought to the surface was only 3.36 per cent., but a very much larger amount than in the former case was left below.

At a colliery in South Wales where the pit is worked on the "separation" system, the book account for one day showed that out of 275 tons 11 cwt. of coal raised, 38 tons 4 cwt. was small, giving a proportion of small to large of rather more than 13 per cent., an exceptionally unfavourable result.

The coal is brought to the surface in "trams," which vary in size and shape in different districts. In some parts of South Wales where the "separation" principle is carried out very strictly these trams consist of a mere open framework of iron on wheels, but in other parts trams with close sides, either of iron or wood, are more generally used. Illustrations of some of the kinds of tram now in general use are given in Plate I. No. 1 is an iron framework tram as used in South Wales, and Nos. 2 and 3 are trams of wood and iron respectively, with close sides. The trams vary in size at different collieries, and in different districts, "thus in Lancashire the capacity "of the trams varies from four to twelve hundredweight; "in Durham and Northumberland from six to twelve

* The Newcastle chaldron is equal to 53 cwt., and differs very much therefore from the London chaldron which weighs only 2,000 lbs,

PLATE I.

Fig. I.

IRON TRAM TO CARRY 1 TON._SOUTH WALES.

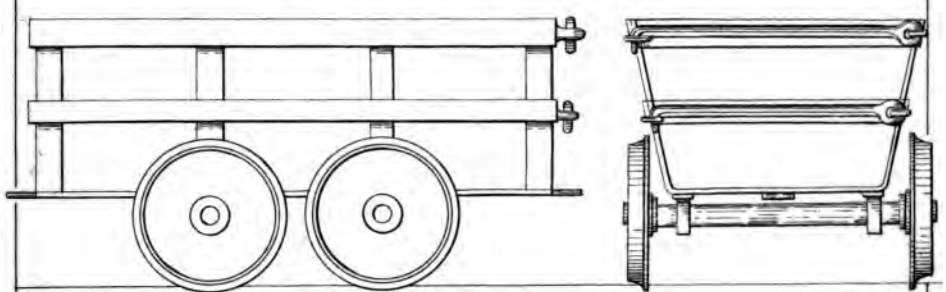


Fig. II.

WOODEN TRAM TO CARRY ABOUT 8 CWT:

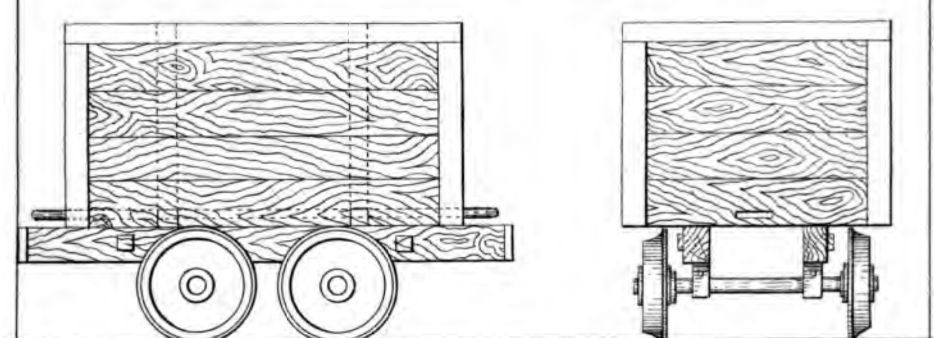
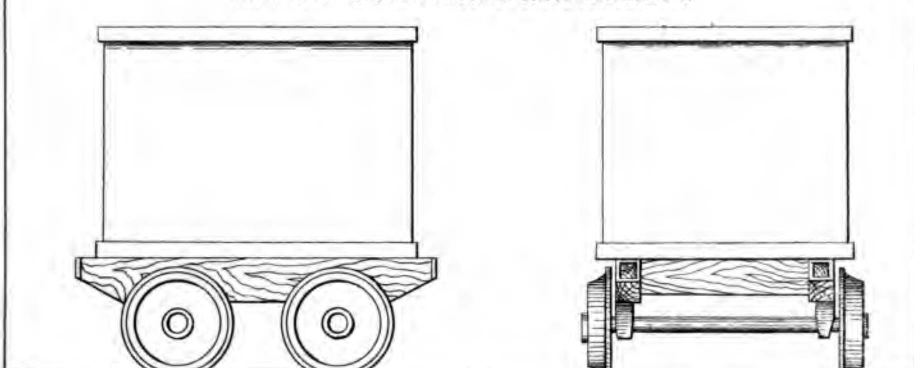


Fig. III.

IRON TRAM TO CARRY ABOUT 9 CWT:_SUNDERLAND.



Scale ½ Inch - 1 Feet.

Metchim & Son, Parliament St.

" hundredweight ; in South Wales (in some of the " bituminous seams) from eight to ten hundredweight; " and in the steam coal, generally from fifteen up to " thirty hundredweight. As a general rule, the size of " the tram depends upon the thickness, inclination, or " peculiar characteristics of the seam, and where such " peculiarities are exceptional, as in an extremely thick " or an extremely thin seam, this may be perfectly correct. " It is conceived, however, that apart from exceptional " circumstances, that is, in seams of average thickness " and inclination, the adoption of a small tram capable of " containing from eight to ten hundredweight is more " productive of economy than that of a larger tram." * In the paper from which the foregoing is quoted, a calculation is made showing the difference in working with small trams as compared with large ones to be nine pence per ton in favour of the former, and at a subsequent page it is stated: " Again, the oftener coal is transferred from " one conveyance to another, the greater, it will be ad- " mitted, is the breakage, and breakage always represents " depreciation in the value of the coal. Now it is sub- " mitted that by the use of the small tram breakage is " saved to a great extent (1st.) because the coal is placed " directly in the tram at the face and not conveyed in " tubs or tramming carts (as where the large tram is " used) and thence loaded into the large tram. (2nd.) " Because in the small tram there is less vertical pressure " than in the large. (3rd.) Because naturally the smaller " the quantity tipped at once the less the breakage; a " ton of coal goes over the tip with considerably greater " force and weight than a few hundredweight " † And these advantages appear to be accompanied by no counteracting disadvantages, for even " in respect of the quantity " of coal raised per day, it is believed that the small tram " will bear favourable comparison with the large." ‡

The cages for raising the coal vary at different collieries. Sometimes there is only one cage which entirely fills the shaft, but at others the shaft is divided and two cages alternately rise and fall, so that whenever the winding

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* " Proceedings of The South Wales Institute of Mining Engineers," vol. VI., p. 174. † Ibid, 183. ‡ Ibid, p. 183.

engine is in motion coal is being raised to the surface. With extremely large trams, these cages are rarely more than single decked, but where small trams are used, the cages have two and sometimes three decks, raising four and six trams at a time respectively.

The "heapstead" is the entire head works of a colliery pit, and comprises the screens, pumping and winding engines, with their respective houses, &c. The platform, on which the full trams are received, on coming to the surface, is usually raised some ten or twelve feet above the ordinary level of the ground, in order to allow space for the slope of the screens, and for wagons to run underneath to receive the coal passing down the screens. The pit-bank is sometimes built up of brickwork, filled with earth or rubbish, and occasionally it is built entirely with stone raised from the pit. Elsewhere a staging of timber supports the upper platform and screens in lieu of a pit-bank; whilst at other places, in heapsteads of more modern construction, the staging is entirely of iron, which last method would appear to be best suited for India, as affording more light and air, and being generally more convenient and cleanly than earthen pit-banks. The flooring, on the level with the pit's mouth, is laid with iron plates. Near the top of the shaft is usually a weighbridge, for the convenience of checking the amount of coal sent up, as the colliers are paid by the ton.* In some cases the table of the weighbridge is suspended from one end of a steel-yard beam, the index end of which is inside a small office immediately adjoining, where the tally-man sits, and takes record of the weight of coal brought up.† This is not a good arrangement, as the yoke-bars suspending the table are apt to get in the way; a better, and more general, plan is to have the weigh-table flush with the floor, and the scale-beam passing underneath the floor to the tallyman's office.

In a convenient position, along one side of the heap-

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* I have seen one old-fashioned colliery, near the Tyne Docks, where all payments, including royalty as well as wages, are made by measurement and not by weight. The tram used is the standard of measurement by which payments are made. It holds 8½ hundredweight.

† At some pits, instead of weighing each tram, one is weighed now and then, and from these a general average is struck for the whole day's work.

stead, the screens are generally placed in one row, with just space enough between them for a man to pass down. The form and dimensions of the screens vary in different parts. At the steam collieries in South Wales they are generally from fourteen to sixteen feet long, and from six feet six inches to seven feet six inches wide; the bars do not extend quite the whole length, there being generally a space of eighteen inches to two feet at the bottom of the bars, and sometimes an equal space at the top, of plain sheet iron. The distance between the bars varies from one inch to one and a quarter inch, and sometimes it is even a little wider still. About Newcastle the screens are generally longer, some of them being as much as twenty-four feet long, but the standard width between the screen bars is generally five-eighths of an inch. At the top of the bars is a plate of iron, and the bottom of the screen, for a space of about two feet in length, is turned up in a horizontal position, to prevent the coal from falling over too rapidly into the trucks placed beneath to receive it, whilst at some pits there is also a flap door of iron, suspended near the top of the screen, to receive the coal upon being emptied out from the trams. A man at the bottom of the screen opens and closes this door, at pleasure, by means of a long iron bar with notches cut in near the handle, with which he can fix the door open or keep it closed. One object for thus regulating the fall of coal down the screen is, that at many of the Northumberland pits a good deal of stone and grey coal is sent up in the trams, and this has to be picked out by hand as the coal passes down the screens into the wagons beneath. As a further precaution for cleansing the coal from impurities, a boy, with a pointed pick, is sometimes placed in each wagon, whose duty is to cut any shale or other impurity, which he may discover, out of the larger blocks of coal. At the top of each screen is a rocking table, on to which a tram is run as it comes from the pit, directly after passing the weighing machine. By referring to Plate I. Fig. 1, it will be seen that the South Wales tram has two iron bars in front to hold in the coal; upon arriving at the rocking table, these are unhooked, and the weight of the tram causes the table partially to revolve, thus throwing the tram at an angle, so as empty out all the coal down the screen It is then

pulled back into position, and wheeled away to the pit's mouth again, ready to replace the next full tram in the cage that may come up. In places where trams with close sides are employed, it is clear that the foregoing method of emptying them would not be efficient. In this case, therefore, the rocking table is merely provided with an upright on either side, and a bar across the top, just high enough to allow the tram to pass underneath. These tables revolve on trunnions which work in bearings at a little distance above the level of the platform. Upon the full tram being run on, the table falls completely over, turning the tram nearly topsey-turvey, whilst it is prevented from going too far over, by a brake fitted on one side for that purpose.

There can be little doubt that the screen itself has a great deal to do with the amount of small coal that passes through it. In the first place, the amount of breakage that takes place when the coal falls out of the tram, will probably be found to vary directly with the height from which it falls; and its further disintegration will, to a certain extent, be dependent upon the length of the screen, and the steepness of the incline at which it is set, for upon this latter point will depend the speed at which it slides down. It may be taken as a general rule that the longer the screen, and the steeper the incline, up to a certain point, at which it is fixed, the greater will be the amount of small coal passing through it. In order to prevent, as much as possible, the breakage which must take place during the act of screening, several devices have been tried; the most recent improvements which I have seen in action being what are called "balanced" screens, which are to be met with in South Wales. Many of the screens at the South Wales pits have a balanced shoot at their bottom end, which, by means of counterbalance weights, assumes nearly a horizontal position ordinarily, but gives way under a weight of coal, allowing it to fall gently into the truck, instead of permitting it to rush out of the screen with the full force due to the height down which it has slid, and which must be the case where no such provision is made for breaking the fall. As a further improvement upon this, a second balanced shoot is now sometimes placed at the head of the screen, and receives the coal as it falls from the tram,

allowing it to enter the screen with less violence. In addition to this, the screen itself is also fitted with counterbalance weights, and it is thus held up at a very gentle incline, which increases in steepness with the weight of coal passing over it. All the counterbalances are fitted with friction breaks, by means of which their action may be regulated, or suspended altogether. Although this system of counterbalancing is founded upon what, at first thought, would appear to be correct principles, it is very questionable whether the desired end of causing less breakage in the process of screening can always be relied upon being attained, unless its use is attended with very cautious feeding of the screens, for if they are always kept fully charged, the benefits of the counterbalances will be entirely nullified, and the whole screen will be as though it were a rigid fixture from top to bottom. There also appears to be a disposition amongst the men at the screens to keep the breaks down, and so prevent the counterbalancing machinery from acting as it should do.

It is very clearly to the interest of all concerned that the largest possible proportion of the coal raised should be made available for the market in the shape of "round" coal, and that the least possible amount of "small" coal should be made in its transfer from one place to another: nevertheless this question appears to have hitherto received less attention than its importance would seem to demand. In South Wales, where the "separation" system is very rigidly enforced, and the collier is not paid anything for the small coal that passes through the colliery screens, it has been found necessary, in justice to the collier, to devise some means for accurately ascertaining what proportion of the gross amount sent to the surface is to be deducted on this account. With this view a small apparatus called by the colliers a "Billy-play-fair," is suspended beneath the screens in the manner shown at Plate II. This, it will be seen, consists of an iron trough, with a sort of hopper bottom, into which all the "small" passing through the screen is directed by means of suitably adjusted iron shoots. This trough is suspended by rods passing down on either side of the screen, from a steel-yard weighing apparatus fitted to the staging above, and provided with a dial face, on which a pointer shows the weight contained in the

hopper beneath. In the tally-man's office, which generally commands a full view of these dials, there is a "Billy-boy," who, each time a tram of coal is sent down a screen, records the weight of "small" in the corresponding hopper, and then empties it into a truck placed beneath to receive the screenings, by means of a string with which he opens the hopper bottom, allowing the small coal to fall out. Upon releasing the string a balance weight causes the hopper to close again, and it is then ready for another charge. By this means the amount of small coal is accurately registered, and it has been found that in some of the largest steam collieries in South Wales, the average proportion varies from five to as much as ten per cent. in different pits, although, as has been already shown, it is sometimes even in excess of the latter rate.

Now, it becomes a question deserving of careful consideration, how it is possible that so large an amount of disintegration can have taken place in so short a time as is occupied in the passage of hand picked coal from the collier below to the railway truck at the pit's mouth. In the first place, it must be borne in mind that in these collieries large trams are employed. That as a rule, "the "large tram cannot be taken to the face of the working, "and the collier is therefore always more or less re-"moved from his tram, in some instances twenty yards or "upwards, and he has to carry the coal as he cuts it in "boxes, or in tramming carts, and transfer it thence into "the tram."* A certain amount of breakage must take place in this transfer, which is still further increased by the shaking of the tram in its journey from the "working" to the bottom of the shaft, and then, again further breakage takes place in passing over the screens; the whole depreciation amounting, as has been above stated, to from five to ten per cent. It is clear that a portion of this breakage would be obviated by the use of small trams which could be taken to the face of the working, and it would be still further avoided by sending the coal up "altogether," as the small coal would then fill up the interstices between the larger lumps in the tram, forming

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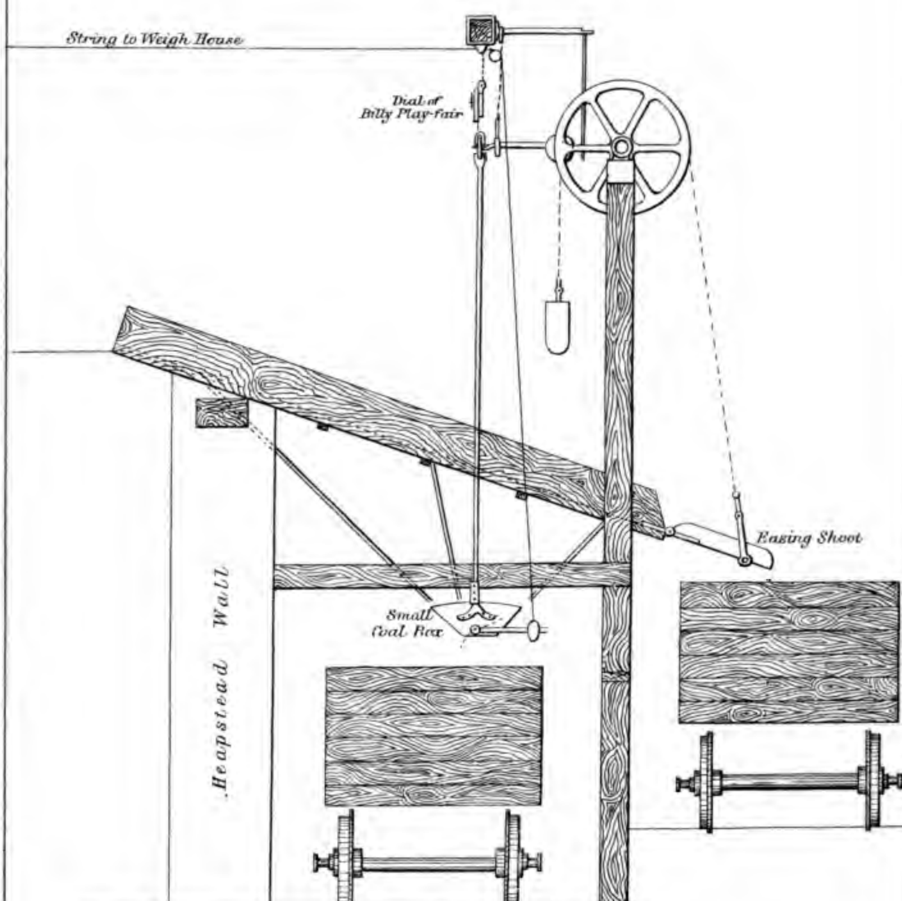
* "Transactions of the South Wales Institute of Mining Engineers," vol. VI., p. 182.

ORDINARY COLLIERY SCREEN, WITH EASING SHOOT.

SOUTH WALES DISTRICT.



Scale ⅛th Inch = 1 Foot.

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a bed for the latter, so that they would not shake about or become so much broken in passing to the bottom of the shaft. How far the small coal would also protect the larger lumps from damage in passing over the screen is a question about which I am at present uncertain. It is quite possible that its presence might be beneficial in that respect, whilst it is very certain that it could not be detrimental by causing any increase of breakage on the screen.

It has been remarked that the angle at which the colliery screen is set is not at all an unimportant consideration in connection with this question of loss by disintegration. From observations made on this subject, it would appear that an angle of twenty degrees is as steep as should be adopted. In setting out plans for a heapstead it is very easy to adopt any angle for the screens that may be desired, but in subsequent stages through which much coal passes, the same precaution is not always possible, as in the case, for instance, of shipping coal, or loading it into barges, where the angle of the shoot or screen is often regulated by the height of the tide, or water in a dock, &c.

Where coal is sent up "altogether" payment is made to the collier for the whole amount, and there is, therefore, no necessity for the "Billy-play-fair." Shoots are placed under the screens to collect all the "small" passing through them, with hopper doors at their lowest point, through which it can be emptied at pleasure into trucks. At most modern works these shoots are constructed of iron, and are completely enclosed, so that no dust escapes to make a mess about the place. With a view to render the foregoing description of screens more intelligible, illustrations of the three kinds referred to have been given in the accompanying Plates II., III., and IV. The first of these illustrates an ordinary fixed screen, with easing shoot worked by counterbalance weight. Plate III. shows a balanced screen, in which there is an easing plate at the top of the screen as well as an easing shoot at the bottom, both worked by counterbalances, whilst the screen itself works upon a hinge at its upper end, its position and angle depending upon the relative weights of the coal upon it and the counterbalance weights attached to its lower end. Plate IV. illustrates the sort of screen

generally in use in the Newcastle districts, with hoppers beneath to receive the screenings.

It has been shown that the amount of small coal obtained at the pit's mouth, even where the colliery is worked on the "separation" principle, is very large, and that when it is worked "altogether," very often as much as one-half of the output consists of small coal. The proper utilization of small coal becomes therefore a question of the greatest importance. From the evidence given by Mr. Isaac Lothian * Bell before Committee B of the Coal Commission, it appears that, "twenty-five or thirty years ago, "there was in the north of England an immense quantity "of small coal raised in connection with the production "of coal for London and other places, where only large "coal was required, and in consequence there was thrown "upon the market an immense quantity of small coal; "in some cases this was left underground, and in others "it was drawn to the surface, and allowed to accumulate, "where it took fire; in fact it was treated almost entirely "as a waste product, so much so that small coal could "be had in any quantity at four shillings a Newcastle "chaldron of fifty-three hundredweight, delivered into "barges on the river. Under these circumstances it was "not surprising that no effort whatever was made "in the direction of economy in its use, for the price of "coal was so small that it would not pay to adopt any "means for avoiding waste. Things are now entirely "changed with regard to the value of fuel, but I am not "prepared to say that there is as complete a change in "the minds of consumers as one would desire to see; for "there is still lingering behind a little of that tendency to "waste which existed when we were getting coal at this "low price. I may state that that coal which was "formerly sold at four shillings per chaldron is now "sold at something like eight shillings a chaldron."

With increased value and price in the market, greater care is now taken in some parts to bring all available small coal into practical use, whilst in others nearly the same reckless waste is observable that formerly prevailed universally in respect to small coal. As the demand for small coal increases, in consequence of the introduction

* "Coal Commissioners Report," vol. II., p. 222.

PLATE III.

Scale 1/8 Inch – 1 Foot.

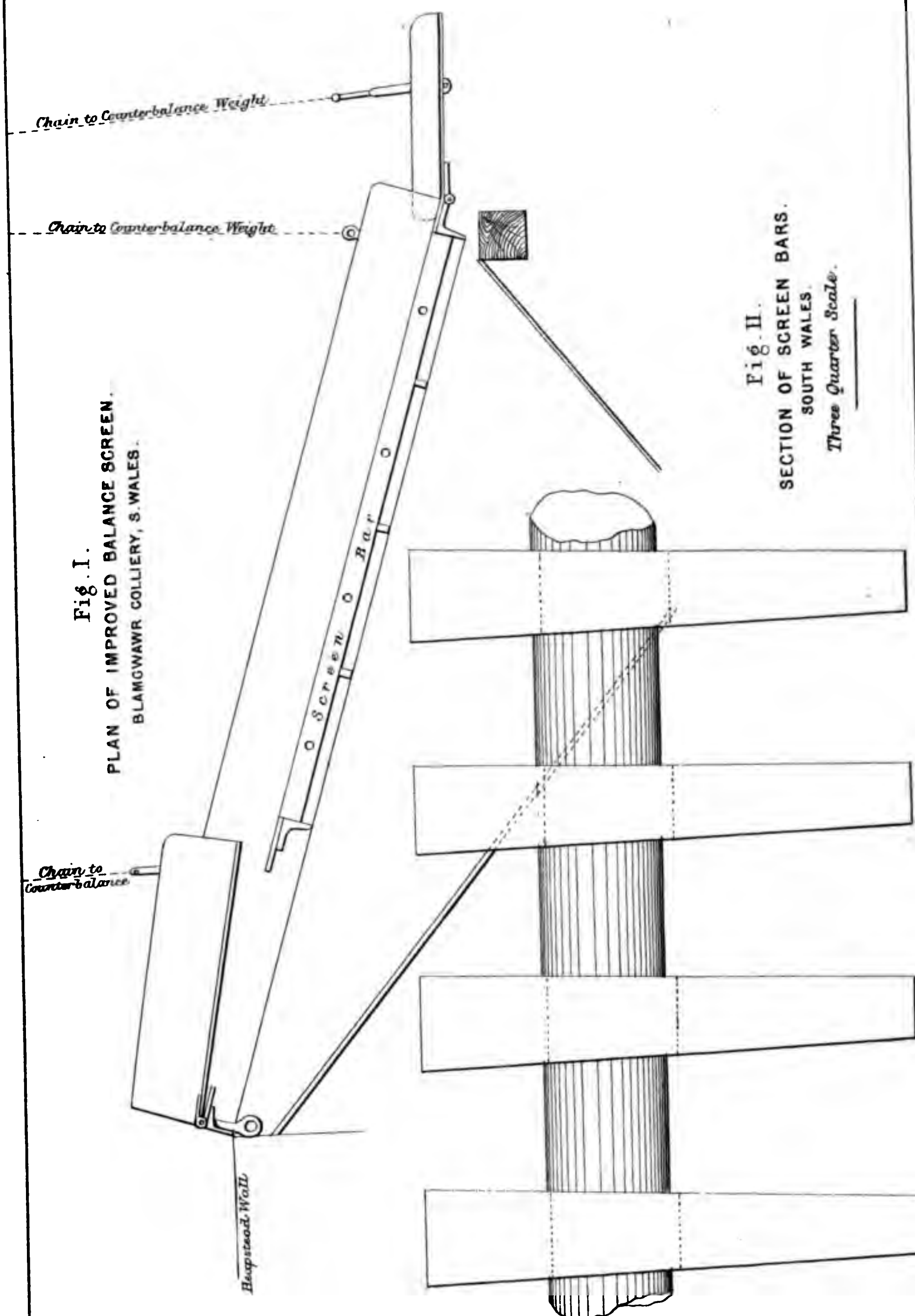

Fig. I.
PLAN OF IMPROVED BALANCE SCREEN.
BLAMGWAWR COLLIERY, S. WALES.

Fig. II.
SECTION OF SCREEN BARS.
SOUTH WALES.
Three Quarter Scale.

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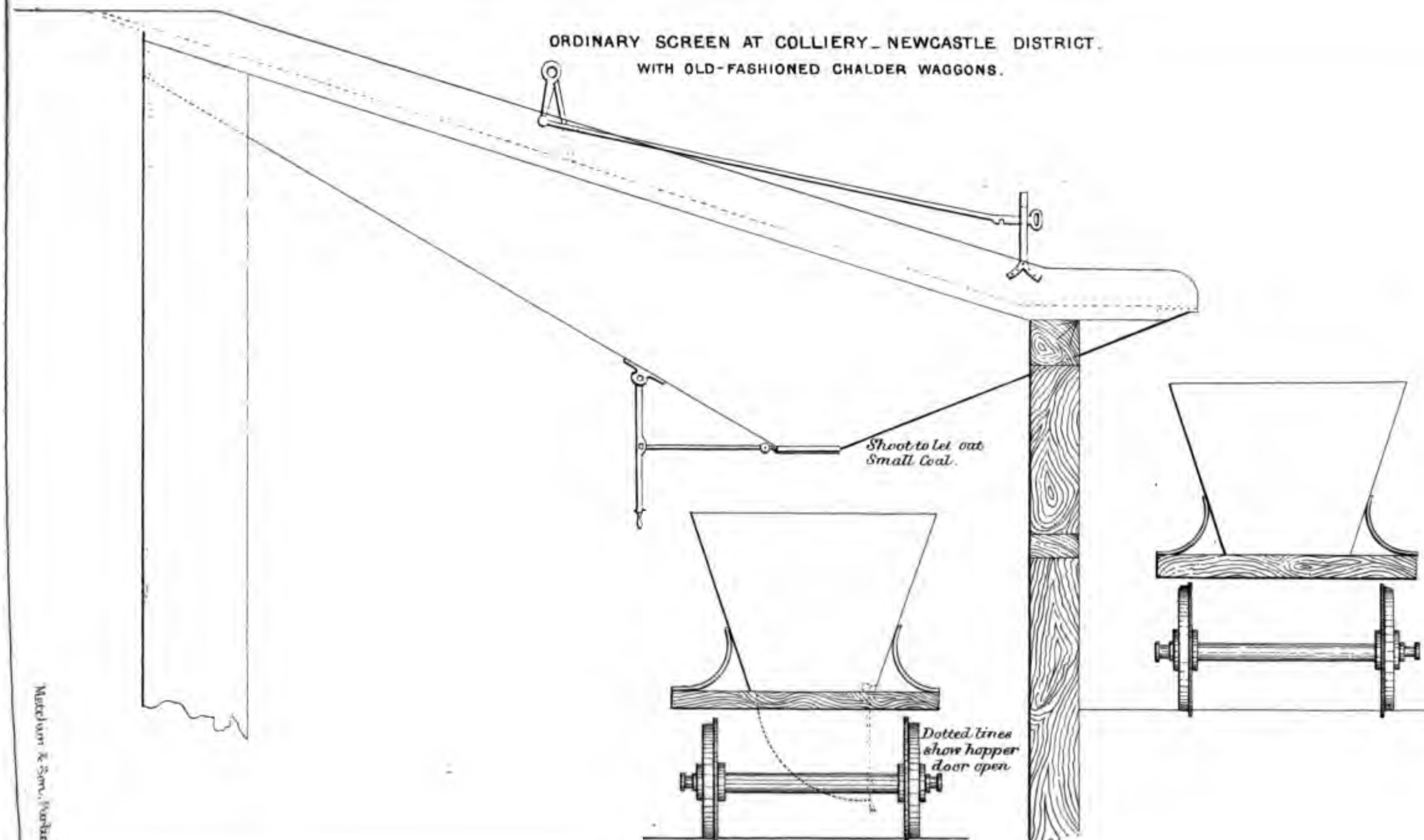
PLATE IV.

Scale ⅛th Inch = 1 Foot.

ORDINARY SCREEN AT COLLIERY _ NEWCASTLE DISTRICT.
WITH OLD-FASHIONED CHALDER WAGGONS.



Matchim & Son, Parliament St.

of new manufactures in which it can be employed, or in adapting existing mechanical appliances so that it can be burned where round coal only is now used, so will the price increase, and it will become more to the advantage of the proprietor to bring all the contents of his colliery to bank. A slight diversion from the subject more particularly under consideration in the present chapter may be here advisable in order to point out what use can now be made of small coal. This article becomes, of course, more valuable to the consumer where it can be used in supercession of round coal than where it is employed for purposes for which round coal is not applicable. Where a demand for coke exists, the small from a bituminous coal can readily be converted into coke, but steam coal will not coke, and that process is not therefore applicable to the small made in the steam coal districts. For this reason it is too often customary to leave it altogether below, notwithstanding that it might be otherwise usefully employed, and no doubt would be so, if it were raised to the surface. Mr. D. Thomson stated before Committee B that "ordinary "small coal used with a Juke's furnace gives just about "the same result as large coal used by hand firing. I "have lately seen furnaces which have been made to "burn small coal in Cornish boilers, where it has been "found to give just as good a result as the large coal "burnt previously; and the simple manner of doing it "was to make a brick arch between the fire and the "crown of the furnace, which causes the combustion of "the gases to go on in a space where there is a suffi-"ciently high temperature to cause perfect combustion." Then there is the process of burning small coal introduced by Mr. T. R. Crampton, but this refers more to dust coal than to what is ordinarily known by the name of "small coal" in the trade. Besides burning it in its natural state, efforts have been made to make coke out of the small of non-coking coals, by first mixing it with a proportion of bituminous matter, or by mixing it with caking coal, but the experiments have not been attended with success. And lastly there is the manufacture of Patent Fuel, which by recent improvements can now be made as suitable for domestic as for steam purposes. The limit of commercial success in the manufacture of Patent

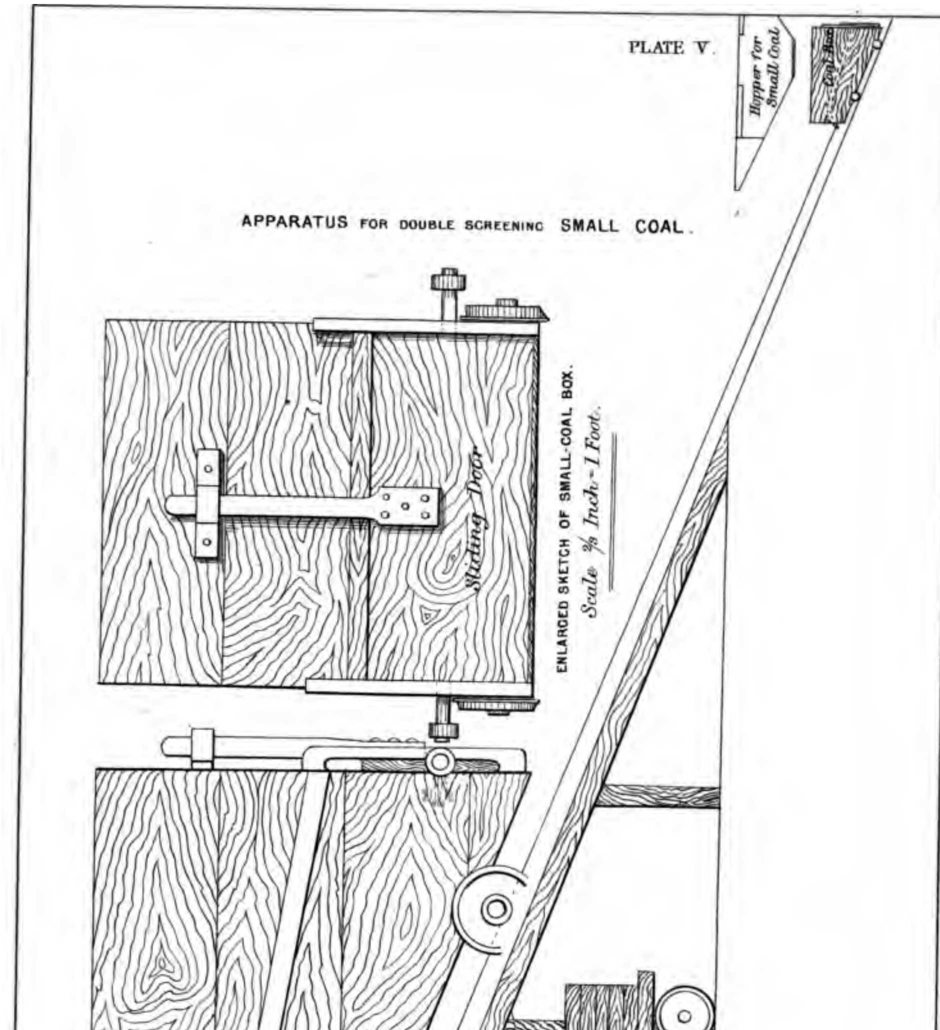
Fuel depends, however, in the difference between the relative values of large and small coal, which must of course be great enough to cover working expenses, leaving at the same time a sufficient margin for profit.

What is comprised under the general term "small coal" varies in different districts, and consists of all that passes through the colliery screens; but as the width between the bars varies from $1\frac{1}{4}$ inches at some collieries in South Wales, to $\frac{5}{8}$ inch which is the general size used in the Newcastle district, it is clear that the former will yield a larger proportion of serviceable coal than the latter. To separate what is serviceable from the dust, small coal is in many places subjected to a further screening, in which it is separated, as has been already explained, into "nuts," "beans," and "dust," which all vary in value, the largest, or nuts, commanding the highest price, and the dust, or duff, the lowest. This second screening is effected by an automatic arrangement which may be thus described:—

Beneath the colliery screens a hole is sunk into the ground at an inclination, having a pair of rails laid down it, and which, extending upwards, are supported at a suitable height by upright posts. At the top of this incline is placed a screen covered in, and having three shoots, under which trucks are placed to receive the different sized coals which fall from them. At the upper part of the screen there is a wire gauze having a mesh three-eighths of an inch square, which separates the duff from the better coal. Below this are steel bars placed seven-sixteenths of an inch apart, and all passing through this forms the "peas" or "beans," whilst the remainder constitutes the "nuts." In order to convey the small coal from the screens, a hopper is placed over the lower part of the incline, where it goes below ground, into which the small coal is first placed. In some cases the small coal falls into this hopper direct from the screens, where such an arrangement is practicable, whilst in others the small coal is received first into hopper wagons, from which it is afterwards emptied into the small coal hopper above mentioned. A tram, especially arranged for the purpose, descends the incline, and by an automatic arrangement opens the hopper mouth, from which it is then charged, and closes it when full. It is then drawn

PLATE V.

APPARATUS FOR DOUBLE SCREENING SMALL COAL.



up the incline by means of a chain attached to the shaft of the winding engine, and being arrived at the top, a door in the side of the tram is opened by a self-acting arrangement, and it empties itself over the screen. The drawing chain is so arranged that the full tram is drawn up to the screen as the cage descends to the pit, and it is let down again when the engine is reversed to draw the cage up again. By this means the process of double screening the small coal is carried on entirely automatically, the only labour required being for the removal of the wagons, placed under the respective shoots, when full, and replacing them by empty wagons. In order to show the relative values of these different sized coal, the following is a list of the quotations of last autumn from a certain colliery for different coals delivered free on board at Sunderland:—

Round coals . .	10*s*. 10*s*. 6*d*. 11*s*.
Treble screened nuts .	8*s*.
Double screened nuts .	7*s*.
Pea nuts . . .	6*s*.
Single screened small .	6*s*.
Pea nuts and duff mixed	4*s*. 6*d*.
Duff	3*s*. 6*d*.

The system of screening small coal above described will be better understood by reference to the accompanying illustration forming Plate V. This shows the kind of screen commonly used in the neighbourhood of Newcastle, and which forms a conspicuous object in the landscape, standing out as it does on one side of the heapstead. I did not meet with any such screens in South Wales, but a somewhat similar screen was in course of erection at one of Powell's Duffryn Collieries, at Mountain Ash, near Aberdare. These screens are sometimes supported by a wooden staging, but they are both more convenient and more sightly when constructed wholly of iron.

This paper being intended only as a record of facts, it is not my intention to enter at present upon any speculations as to how the loss which now takes place at the colliery can best be mitigated or altogether avoided. There is no doubt but that by improved appliances much that is now wasted might be sent into the market as round coal, instead of being thrown on one side as "small" or "duff." In a country like England, where

coal exists in such abundance, the importance of enforcing economy in this respect is entirely overlooked, neither does it appear to be very much to the interest of those who work the collieries to take much trouble about the matter, or we should most certainly find a little more care than is now exhibited for the better protection and preservation of coal. In a country like India where the production of coal is so small, the yield not having as yet reached so much as one million tons in a whole year, whilst the demands for locomotive purposes must continually be on the increase, the importance of economising every ton of coal cannot well be over estimated. In the evidence given by Sir Daniel Gooch before Committee B of the Coal Commission, it appears that upon most railways in the United Kingdom "the quantity of coal used in the locomotive engines varies from thirty-eight pounds to forty-five pounds per mile, whereas by arrangements introduced by Mr. Joseph Beattie, it has been reduced on the railway of which he is engineer (the London and South Western Railway) to twenty-five pounds per mile." Now it is well known that the steam producing properties of Indian coal are considerably inferior to those of our English steam coals, and by comparing the amount of coal burned by the East India Railway in 1866 (the latest date for which I possess returns) with the mileage run in that year, the average consumption is found to have been 80·4 pounds per mile run. If now we take it at eighty pounds per mile, and apply that rate to the 14,396,790 train miles run by all the railways in India during 1870, it will be found that had Indian coal been used exclusively for fuel on these lines, they would have consumed no less than 514,171 tons, or an amount very nearly equal to the whole quantity raised in India in the year 1868 (547,971 tons).

Although the duty performed by Indian coal is inferior to that obtained from English coal, the difference in the price between the two in India turns the scale considerably in favour of using the native fuel. From a recent report on experiments made with coal from the Mayo colliery it appears that notwithstanding the cost of the coal from Chanda was as high as thirty shillings per ton, it proved 20 per cent. cheaper than English coal on the Nagpore Extension Railway.

The foregoing remarks relative to the importance of protecting Indian coal, as far as possible, from deterioration by disintegration in the several processes through which it has to pass at the colliery, apply equally with reference to the questions considered in the following chapters.

Since the above was written, the Administration Report of the Railway Department in the Bombay Presidency for the year 1870–71, has arrived, and contains some valuable information on the comparative cost of working the Great Indian Peninsula Railway with English, Mopani, and Chanda coal. The cost of carriage in each case is set down at four pies, or one halfpenny, per ton per mile. The price of English coal is taken at Rs. 25 a ton at Bombay; of Mopani coal, Rs. 13 : 8 per one and a half tons at the pits; and of Chanda coal Rs. 6 per one and a half tons, also at the pits. From the statement given of the value of coal at each depôt along the line, "it would appear that, as long as the selling price of "English coal is Rs. 25 per ton, loaded into trucks at "Bombay, the Railway Company will save about "Rs. 4,77,000 per annum by having access to Mopani "coal. If they had access to both Chanda and Mopani "coal, their saving would be Rs. 9,00,000; if to Chanda, "without Mopani, Rs. 8,28,000. Mopani coal, till com-"pletion of branch, is delivered at Gurrawarra by cart "for Rs. $2\frac{1}{2}$ per ton, or Rs. $2\frac{1}{4}$ more than it will cost on "completion of branch. Allowing for the increased "quantity of Mopani coal, in comparison to English coal, "the loss to the Company by non-completion of the "branch is about Rs. 1,31,600 per annum. But this is "on the assumption that the Mopani Company can supply "58,500 tons per annum. They, however, cannot as yet "furnish more than 1,200 to 1,500 tons per mensem, or "say 20,000 tons per annum. On this quantity the "actual loss will be Rs. 45,000 per annum."

I have quoted the above extract as an evidence of the great importance that the speedy development of the coal resources of India is to the railway interests there.

CHAPTER III.

On the Railway.

Breakage of Coal in Railway transit—Difficulty of correctly estimating to what extent that occurs—Deterioration of Coal from exposure to the atmosphere—Small Coal with large in Railway wagons—Springs on Coal wagons—Importance of slow speed—Increase in size of Railway Coal wagons—Objections to Newcastle "Chalder" wagons—Largest wagons inapplicable at South Wales shipping ports—Different kinds of Coal wagons now in use—Locomotives in use for Coal traffic on different lines of Railway—Permanent way—Double-headed Rails—Longitudinal and Cross Sleepers—Weight of Rails on different lines.—Chairs and Fish-plates —Endurance of Rails—Iron and Steel Rails—Which is cheapest in the long run—Iron Rails for India—Traffic not sufficient to justify the use of Steel Rails in India—Destruction of Rails on inclines—Destructive effects of a high speed—Slow speeds most economical for Mineral traffic—Weight of Trains regulated by ruling gradient on line of Railway—Ruling gradients on different lines—Weight of Coal Trains on different lines—Cost of Coal Carriages on Railways—Break of gauge.

There can be no question but that a vast amount of depreciation takes place in coal during its transit by railway. It is not possible, however, to test the amount of breakage which is fairly due to this cause, for so many other circumstances may have to be taken into consideration in connection with that question, that to attempt to lay down any average for the amount of small coal due to abraison of blocks of coals against one another in the railway truck, would be useless, unless as the result of actual experiments made with different kinds of coal, and extending over a lengthened period. In order fairly to test this question it would be important that the coal should be drawn away from the colliery with as little delay as possible after the trucks are loaded, and that the latter should be speedily unloaded with due care to prevent, as much as possible, breakage taking place during that process. The necessity for avoiding delay arises from the fact that all coal has a tendency to disin-

tegrate by expose to the atmosphere, the extent to which this takes place varying, however, very considerably with different kinds of coal. In Indian coal deterioration from exposure appears to take place to a far greater extent than in English, which is no doubt in some measure due to the friable nature of the coal itself, but to a still greater extent to the climate, for even in this country the disintegration of stored coal goes on at a much greater rate in warm, dry weather than in the wet and cold seasons, hence the practice of stacking coal should be avoided as far as possible, and no unnecessary delay should be permitted to occur in conveying it from the colliery to the depôt.

From observations which I have been enabled to make, I do not think that the amount of disintegration of coal in a railway wagon increases in proportion to the length of the journey, but I am of opinion, on the contrary, that after the first few miles the large lumps form for themselves a sort of bed of small coal by grinding away all the obtrusive sharp corners and points, and that after a certain amount of mutual destruction, any further similar destruction takes place at a very slow rate, if indeed it occurs at all. If this conclusion be correct, then it would appear that screening at the pit's mouth, so far from being advantageous, is really detrimental, for if a certain proportion of small coal in the case of "altogether coal" workings, and all that is sent to bank in "separation" collieries were permitted to remain in it, the probability is that less destruction would take place during the railway journey; the requisite amount of small coal to form a bed for the larger lumps being placed together with them into the truck, separating them from one another by filling up the interstices between them, and so, in a great measure, preventing the process of loss and destruction which otherwise prevails. Some of the older classes of coal truck are without springs, but it is always customary now to make them with springs, in order to avoid, as much as possible, the jolting which is inseparable from railway travelling, and which cannot but assist in the destruction of the coal. The more this can be avoided by the introduction of improved appliances, the less will be the loss resulting from breakage of coal in railway trucks. It is

a fortunate circumstance that the interests of coal and the economy of railway working are identical, insomuch that a slow speed will produce less concussion than a high speed, and consequently less breakage, and a low speed with the heaviest practicable train constitutes the perfection of economy in goods or mineral traffic. One of the most noticeable features in modern coal trucks is their tendency to increase in size and capacity. Perhaps the old "Chalder" wagon of the Newcastle district, which holds only fifty-three hundred weight, is the smallest coal wagon now in use; and besides the inconvenience of its restricted capacity, it possesses another disadvantage in its great depth, and the consequent vertical pressure of the upper layers of coal upon that which is at the bottom of the truck. In order to increase the carrying capacity of these trucks, many of them has been raised some nine or ten inches in height, whereby they are increased to the extent of being able to carry four tons each. Thus, although the object is certainly attained of carrying a greater weight upon two pairs of wheels, it has only been accomplished at the cost of increased vertical height of load, accompanied by an increase of the evils arising therefrom, which have already been pointed out. The carrying capacity of coal wagons generally has been very much increased of late years, and the largest on the four feet eight and a half inches gauge now are capable of holding as much as ten tons, but there are also a large number still in use, which hold but six, seven, or eight tons. In some instances the largest class of wagons is inapplicable for the shipping trade, in consequence of their length being too great for the tipping machinery originally made to suit the size of smaller trucks, and consequently we find a majority of the smaller trucks in use in the neighbourhood of the South Wales shipping ports, but for ultimate economy the larger wagons are to be preferred.

There are three principal kinds of wagon in use for coal traffic, viz.: 1. Those having an end door, used principally for shipping coal in South Wales. 2. Those with side doors as well as end door. This is the most favourite wagon for long journeys and general purposes, as it is adapted not only for discharging coal into ships from the end of the wagon, but also for unloading at either side. 3. Hopper bottom wagons having neither

side nor end doors. These wagons were made specially for carrying gas coal from Newcastle to London, but they are now also a good deal used in the house coal trade.

But little need be said here on the subject of locomotives for coal traffic, as that is a question so well understood now that no remarks of mine would be calculated to add materially to what is already known. On all the lines which I have visited, six coupled engines exclusively are used for coal, and indeed for goods traffic generally. They vary in weight, however, with the circumstances of each line and the fancy of the locomotive engineer.

With regard to the permanent way of coal carrying lines in England, the following particulars may be of interest in connection with the general question of mineral traffic. With the exception of the Great Western Railway, along a portion of its length, double headed rails are almost universal on the lines mentioned already as having been visited for the purposes of the present report. Although that section is used, the rail is not reversed on all of those lines. On the Great Eastern Railway they are reversed, as also on the North Eastern. On the latter line the chairs are fitted with wooden cushions to prevent the indentation of the under face, which otherwise takes place. On some lines, such as the Great Western and Great Northern, the double headed section is adhered to in principle, whilst it has not been considered desirable to reverse the rail, and the upper and lower heads have accordingly been made of different sections. Advocates for double headed rails still exist, although they are not now much used abroad, but they are very general throughout the English lines of railway. With regard to the question of the best section for a rail, a great deal of very valuable information will be found in the Minutes of Proceedings of the Institution of Civil Engineers, Vol. XXVII. pages 321 to 409.*

The Great Western Railway is the only line having longitudinal sleepers, on all the others cross sleepers are used. Longitudinal sleepers are, however, gradually being abandoned by the Great Western Railway Company in favour of the cross sleepers, which are more

* "The Manufacture and Wear of Rails." By Christer Peter Sandberg, Assoc. Inst. C.E., and discussion thereon.

favourable to the durability of the rails as well as of the rolling stock, in consequence of the greater elasticity which they impart to the permanent way.

The following table gives some particulars relative to the permanent way of the lines above named:—

Railway.	Weight of rails per yd.		Weight of Chairs.	Weight of Fish Plates per pair.
	Iron.	Steel.		
	lbs.	lbs.	lbs.	lbs.
Taff Vale............	78	74	mid-chair 27 joint-chair 32	27
Blyth and Tyne ...	75	—	43	22
North Eastern......	80	—	32 to 37	24
Great Western......	80	80	34	23
Great Northern ...	80	80	40	24
London and North Western	84	84	40½	23
Great Eastern	82	75	36	22

Mr. R. Price Williams* has laid it down as the result of his experience that *the endurance of rails may be measured by the product of the speed and the passing weight*, and this rule has subsequently been confirmed by experiments on the Great Northern Railway, as well as from the results of the wear of rails on the lines belonging to the Swedish Government Railway Administration. From an annuity table of the average life of rails, compiled by Mr. C. P. Sandberg,† it appears "that solid steel rails "are the cheapest up to ten years' wear of iron rails; "that steel-headed rails are cheapest for between ten and "twenty years; and that iron rails are cheapest when "they last twenty years or more. The amount of traffic "must, therefore, decide which material it is the most "economical to use for the maintenance of the permanant "way. For all railways where ordinary iron rails are

* "Minutes of Proceedings of the Institution of Civil Engineers," vol. XXV., p. 353.

† Ibid., vol. XXVII., p. 329.

" worn out in five years, or in a shorter time, solid steel " rails are the most economical; but where ordinary iron " rails last over ten and up to fifteen years steel-headed " rails would be the cheapest; iron rails in these cases " being clearly proved to be the most expensive, although " the cheapest where they last from fifteen to twenty " years and upwards."

Experiments made on the Great Northern Railway and on the Swedish railways seem to indicate "that two " hundred and twenty millions of tons may be carried " over good iron rails at a speed of one mile per hour, so " that any Railway Company knowing the load which " passes annually over their line and the speed of the " trains may, by multiplying the one into the other, and " dividing two hundred and twenty millions by this pro- " duct ascertain the life of iron rails in years."* In applying this calculation with reference to Indian railways, another important item for consideration is the cost of freight, but even with this in its favour it is hardly probable that the traffic of Indian railways will for many years to come be such as to necessitate the use of steel rails in their construction. With a sufficient increase of traffic, however, to justify the use of steel, it can at any time hereafter be employed instead of iron rails when the latter require renewal. But although it would not appear advisable at the present time to lay down new lines in India entirely with steel rails, they might without doubt be beneficially used upon all steep inclines, and especially where the incline is in favour of the heaviest traffic carried, for although it would at first appear most probable that the greatest amount of wear would take place in ascending an incline with a heavy load, experiences on the Great Northern Railway have proved that far greater destruction of the rails takes place on the down-hill inclines than on those of the up-hill inclines with an equal amount of traffic. This difference in the destruction of rails differently situated is no doubt owing to the percussive effects due to speed in destroying the rails, and which it has been stated † increase probably as the square

* "Minutes of Proceedings of the Institution of Civil Engineers," vol. XXVII., p. 325.

† "Minutes of Proceedings of the Institution of Civil Engineers," vol. XXV., p. 400.

of the velocity. This brings us to a consideration of the speed at which coal traffic can be most economically conducted, a question which has reference not only to the preservation of the permanent way of the line, but also to the breakage of coal in transit and to the time occupied. The first and second of these points are in harmony with one another, and both are in favour of a very slow traffic; but in the third case, speed is the all-important element. It is not now intended to enter into any lengthened considerations on these different questions, but merely to state what is actually accomplished with the coal traffic on those lines which I have visited. On the more strictly mineral lines of railway, no interference to the mineral traffic is occasioned by the passenger trains, and the speed of the former can be regulated with a view to the attainment of the most economical results; but it is otherwise on those lines where there exists a large passenger traffic. In 1861, a letter was addressed by Mr. G. R. Stephenson to the President of the Board of Trade, as to the desirability of slow speeds upon railways for conveying mineral traffic, and it was shown in that letter that if the mineral traffic were separated from the passenger traffic, and a slower speed adopted for the former, it could be carried with much less destruction to the rails and rolling stock, and therefore with more economy. It has been stated in a previous part of this paper that the weight of goods trains is regulated principally by the ruling gradient on any line of railway, and the nature of the line generally will also in a great measure regulate the possible speed. On the Taff Vale Railway the gradients are all in one direction, and that in favour of the load. The whole system comprises about sixty-four miles, but the greatest distance between the termini is twenty-four miles. On this railway there are three inclines of 1 in 40, and one short piece of 1 in 32, but the prevailing gradient is 1 in 200. On the exclusively mineral branches there are curves of five and six chains radius, and on the main line there are several of ten and fifteen chains. All the heavy coal traffic is, as has been already stated, down the incline, and the return empties have consequently an ascending gradient the whole way. Coal trains, when full, consist generally of about eighty wagons, each holding on an average seven tons of coal.

The weight of each wagon averages three tons fourteen hundred weight, and the total gross weight of the whole train, including engine and tender, would thus amount to rather over nine hundred tons. In this case, however, it is clear that the weight of train is not dependent upon the line, but its length is probably regulated from considerations of convenience, and the number of wagons is limited accordingly. The speed down with full trains is not allowed to exceed twelve miles per hour, but the return trains of empties are permitted to go at the speed of sixteen miles per hour. The Blyth and Tyne Railway consists altogether of thirty-eight miles of line, the longest lead from the colliery to the Sunderland Docks being sixteen miles, and the shortest six miles. There is only one gradient on this line of any importance, which rises about 1 in 100 continuously for three-and-a-half miles in length; there are curves as sharp as ten chains radius. The wagons on this railway are all of the old-fashioned "Chalder" type, holding fifty-three hundred weight each. The maximum load for a train is about forty-eight chaldrons, or a net weight of coal of about one hundred and twenty-seven tons. There is no l mit to the speed of mineral trains, but they average on this line about twenty miles an hour.

A very extensive coal traffic is carried on the North Eastern Railway Company and its several branches. The line has a falling gradient all in favour of the coal traffic, and the trains carry from two hundred to three hundred tons net weight, in from twenty to forty wagons of about eight tons each. Recently some new wagons have been added to the rolling stock of this line holding ten tons each. The maximum speed allowed for coal trains is from seventeen to twenty miles an hour. The Great Western Railway conveys coal to Birkenhead and to London, and is in connection with both the North and South Wales coal fields. The broad gauge is now being entirely done away with by degrees, and the narrow gauge is now being laid down all along the South Wales Railway. The weight of mineral trains varies very much over different parts of the line, and is dependent on the section of the district run over. Thus, on the broad gauge they draw trains carrying five hundred tons net load from Swindon to London, but only about half that

weight can be conveyed between Gloucester and Swindon; so, at the latter place, two trains are often joined together for the journey on to London. On the Gloucester and Swindon section there is a heavy incline about four miles in length, with gradients of 1 in 60, 1 in 70, 1 in 75, 1 in 94, and 1 in 100; between Swindon and London the steepest gradient is 1 in 660, of which there are only two short lengths, the next steepest gradient being 1 in 754. The Great Northern Railway draws coal from the Yorkshire and Durham coal fields, and takes on trucks from the North Eastern line at Doncaster. The ruling gradient between Doncaster and London is 1 in 200. An extreme train consists of thirty trucks, holding ten tons each, and two brakes; but an average train would consist of from thirty to thirty-five wagons, holding about seven tons each. The speed at which these trains travel varies between twenty and twenty-five miles per hour. The North Western Railway line, over which the coal traffic runs between Wigan and London, has a ruling gradient of 1 in 100 for a distance of less than a quarter of a mile, the next steepest being one of 1 in 177 for three miles. The trains from the Wigan Collieries average about thirty-three trucks, holding seven tons of coal each. Return trains of empties are made up, consisting of about fifty wagons each. The Great Eastern Railway does not furnish, from the working of its mineral traffic, the same useful information which has been given above relative to other lines, from the circumstances that exceptional conditions prevail on the line. The ruling gradient against the coal traffic on this railway is 1 in 135, but there is a bank thirteen miles long with an almost continuous rise the whole way, and with gradients varying from 1 in 135 to 1 in 768, over which the coal traffic has to pass, and the weight of train that can be drawn by a single engine is thereby very considerably limited.

The cost of conveying coal by railway varies on different lines, the rate per mile being, as a rule, inversely as the distance. Thus, on the Taff Vale Railway, where the lead in no case exceeds twenty-four miles, the charge—when the wagon is the property of the railway—is one penny per ton per mile; and when the coal is drawn in wagons belonging to the colliery proprietors,

seven-eighths of a penny per ton per mile. The above charges are made up in the following manner:—four-eighths of a penny per ton per mile for road toll, three-eighths of a penny for locomotive expenses, and one-eighth of a penny for wagon hire. On the Blyth and Tyne Line the wagons almost all belong to the Railway Company, and their charge, inclusive of wagon hire, is one penny and an eighth per ton per mile. The longest lead on this line is only sixteen miles. On the North Eastern Railway the charge varies with the distance, but, exclusive of wagon hire, and for distances exceeding forty miles one half-penny to three farthings per ton per mile is considered to be a remunerative rate, when carried in full tram loads. The standard rates for coal traffic on the Great Western Railway are one half-penny per ton per mile, with a terminal rate of one shilling and six-pence per ton. These prices are, however, seldom obtained, owing to the competition between different lines. The charges actually made average from one quarter to a little over one-third of a penny per ton per mile. When the Company supplies wagons, their charge for the use of them varies from one-eighth to one-sixteenth of a penny per ton per mile. On the Great Northern Railway the rate for coal carriage is at the present time as low as one-third of a penny per ton per mile, exclusive of trucks, which is scarcely more than sufficient to cover working expenses, but the price has been brought down so low owing to competition with other lines. The book charges on the London and North Western Railway are as follows:—When the coal is conveyed to country stations, having been conveyed for one hundred miles or upwards, from one half-penny to three farthings per ton per mile, with a terminal charge of four pence per ton. Coal carried to London is charged at rates varying from ·45 of a penny per ton per mile for one hundred miles. to ·40 of a penny per ton per mile for two hundred miles, with, in each case, a terminal rate of nine pence per ton. Whether these rates are always obtained in full, however, is questionable, as they are no doubt affected by competition in the same way as on other lines. On the Midland line, the carrying rate to London is, at present, about one-third of a penny per ton per mile, in addition to a terminal rate, which may be made matter of arrangement.

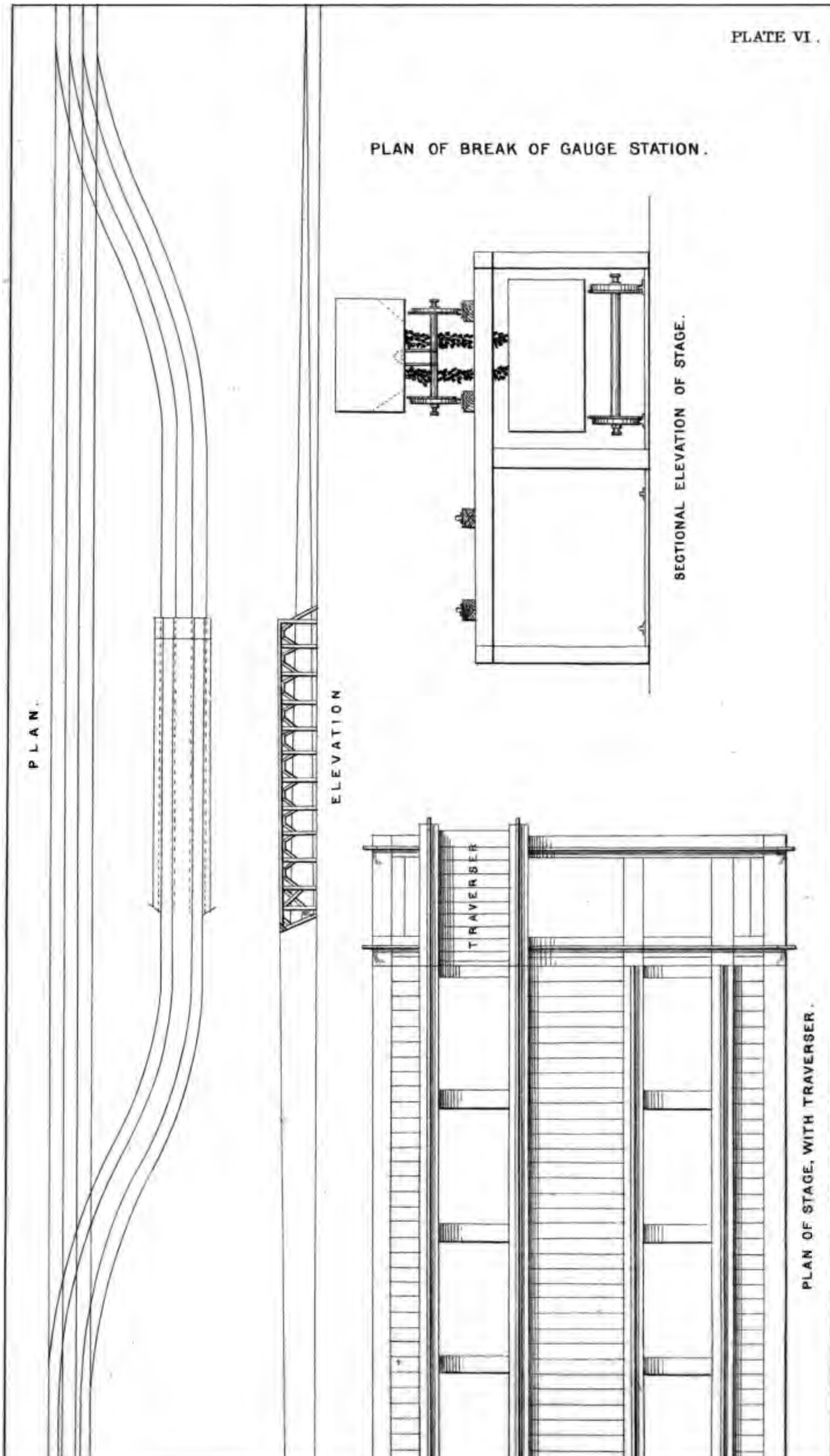
Reviewing the charges above given, and taking it in all cases exclusive of wagon hire, it seems that, for a maximum lead of sixteen miles, on a mineral railway, the charge is one penny per ton per mile, and for a maximum lead of twenty-four miles, seven-eighths of a penny per ton. In both these cases, however, it should be stated that exceptional charges are made when the lead is very short, such as five or six miles only. For long journeys of over one hundred miles, probably one-third of a penny per ton, with a small terminal charge would be productive provided very long trains can be run through; but where, owing to heavy gradients, it is only possible to take coal trains of moderate dimensions, it is clear that the same charge would not prove remunerative; for, whereas in the former case, one engine only would be necessary to draw a certain weight of coals, in the latter one and a half, or perhaps even more engines would be required to do the same work, accompanied by a proportional increase of train staff, such as drivers, firemen, and guards.

In connection with this part of the general question of coal *carriage*, there only now remains to make a few observations on the subject of break of gauge, which is one likely to be of considerable importance in India, where lines on the new standard of narrow gauge will probably before long convey the products of many hitherto undiscovered coalfields to the existing broad gauge railways, both for locomotive purposes and for distribution throughout the districts through which they pass.

Before the narrow gauge was laid down on the Great Western Railway up to London, there was a break of gauge at Wolverhampton, at which place coal arrived in narrow gauge wagons for transmission to London, and it had, of course, to be transferred from them into broad gauge wagons. In order to effect this transfer rapidly and cheaply, the following plan was adopted, which will be better understood by referring to Plate No. VI. Advantage was taken for the changing station of a position where the line was on an incline, so that it was easy to connect branches on two different levels with the main line, within a short distance of each other, without the necessity of constructing either on a very steep gradient.

PLATE VI.

PLAN OF BREAK OF GAUGE STATION.



Metchim & Son, Parliament St.

These branches ran towards each other, the narrow gauge branch being constructed on the higher level, and carried over a raised viaduct at its further extremity, whilst the broad gauge branch was formed on a lower level, and ran under the viaduct above referred to; so that the broad gauge coal wagons were thus brought directly under those belonging to the narrow gauge line, and the latter, being all hopper-bottomed wagons, were enabled simply to drop their contents into the wagons below them, which were of such a size as to hold exactly the contents of two of the smaller wagons. The cost of this transferring of coal was found to average, as nearly as possible, one penny per ton. By having a double row of lines, both above and below, each being fitted with a traverser at its extreme end, this system of transfer might be carried on as fast as the trains of loaded wagons could be brought up, which, with a well organised system, might be almost continuously; at the same time, both trains of wagons being removed from the main line during the process, no interruption would be caused to the other traffic. The Engineer of the Great Western Railway is not aware that drawings ever existed of this exchange siding at Wolverhampton, which, he believes, was constructed without any such preliminary preparation of details. My illustration at Plate No. VI. has been constructed from the description given to me by Mr. Thomas, the Engineer to the Great Western Railway, at Paddington.

NOTE.—In Mr. Spooner's recent work on "Narrow Gauge Railways," illustrations are given, at page 78, of cross sections of sidings near Minfordd, at the junction of the Festiniog and Cambrian Railways, for the transhipment of slates, minerals and goods from off and on to the 2 feet, and the 4 ft. 8½ in. gauges. For minerals a tipping arrangement is adopted for wagons with side doors, the wagons being placed on a rocking platform which is tipped by means of a worm working into a toothed quadrant beneath, similar to what is described at pages 60 and 61. This plan would not be either so cheap or expeditious for coal as that above referred to, and it is not therefore thought necessary to give any further description of it here.

CHAPTER IV.

At the Depôt.

Deterioration of Coal by exposure to the atmosphere—Should be used as soon as possible after being raised—Necessity for Coal Stores—Stacking of Coal in the open air—Recent introduction of Covered Depôts—Destruction of Coal greater in hot dry weather than in moist or cold—Liability of Indian Coal to disintegration—Covered Stores should be provided in India—Stations where Railways run on a high level best adapted for Covered Depôts—When this is not the case the Coal heap should be placed well under cover by hand—Spontaneous combustion, and means for preventing it—High Level Depôts—Principle upon which modern Coal Depôts are constructed—Use of hopper bottomed wagons—A simple form of high level Coal Depôt—Mode of carting Coal away—Vertical fall—Inclined shoot—Introduction of screen with the inclined shoot—Place of screen in the shoot—Small Coal—Hopper at top of shoot Bars of screens—Grappling irons—Poupard's sacking apparatus—Depôt for storeing Coal—Depth of vertical fall—Suggestions for a counterbalanced arrangement for emptying wagons—Amount of small Coal collected at Staiths—Importance of protecting Coal from atmospheric influences—Cause of the "weathering" of Coal—Analysis of Indian Coals—Covered stores especially necessary in India—Iron pyrites—Manufacture of copperas and of sulphuric acid—Spontaneous combustion—Arrangement of lines of rail leading to the Depôt—Roof over Depôt—Screening Coal—Portable screen for stacking yards—Illustrations.

All coal deteriorates to a greater or less degree upon exposure to the atmosphere, not only by disintegration but also by a loss of its heating properties; and it has been estimated that, in this latter respect, its powers for raising steam will be reduced by one half after lying in the open air for six months. The most economical application of coal would therefore be to bring it into use immediately upon its being raised from the pit, or, at least, upon its reaching the great centres of consumption to which it should be conveyed with no more delay than may be unavoidable. It is unnecessary to explain here that this is in most cases impracticable, and hence it becomes necessary to provide storeage accommodation for

fuel at different convenient centres, whence it may be withdrawn for use as required. Until quite recently coal trains were drawn on to railway sidings, set apart for the purpose, and the coal was thrown out by hand and stacked alonside the rails, exposed to all the effects of the climate. Improvements have now, however, been introduced in this respect, and the coal is brought up in hopper bottomed trucks, taken under cover and deposited, with such care as can be conveniently given, into suitable vaults protected from the weather, or sent down a shoot and placed at once into sacks, by means of a convenient arrangement, in the case of house coal wanted for immediate sale. Although these improved depôts are now being rapidly extended throughout London, a very large quantity of coal is still stacked in the open air at those depôts where, either from the supply of coal sent there not being sufficient to warrant the necessary expenditure for their construction, or from the apathy of the coal merchants trading from those depôts, these improved bays have not yet been introduced.

Coal thus exposed to the atmosphere is found to fall to pieces much more in the hot and dry seasons than during the winter months, and, with the same coal, this deterioration would therefore be likely to take place to a far greater extent in India than it does in England. Much of the Indian coal, however, has been found peculiarly liable to this disintegration from exposure, and that raised from the new Chanda coalfields is reported to have so fallen to pieces, after a short exposure, as to render it totally unfit as fuel for locomotive purposes. If the native coal of India is to be used for the railways—and there can be no doubt upon this point—some means must be devised so as to enable it to bear storeage; and if it is worth while to incur expense in the provision of suitable accommodation for the storeage and protection of coal in England, it must be still better worth while to do so in India, where, at present, fuel is so much more scarce and more liable to injury from exposure. Notwithstanding the drawbacks and disadvantages of stacking coal in the open air, that practice is still very largely resorted to, especially in places where the railway runs on a level with the ground, for it is only when the line is carried on a high level that the modern system of constructing coal

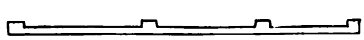
depôts can be introduced with all its advantages. For small depôts on the Indian lines of railway, and particularly where they run on a level with the country or in cuttings, the system now generally adopted about London for storing coal would hardly be applicable except at some considerable cost, which would probably be wholly disproportioned to the advantages to be derived therefrom. At such depôts, the old-fashioned system of emptying coal wagons by hand, and stacking the coal will most probably be adhered to; but under all circumstances the store heap should be kept well under cover, and protected as much as possible from atmospheric exposure. I am aware that one of the principal objections to storing Indian coal is that it is liable to ignition from spontaneous combustion, in consequence of the presence of iron pyrites with which most of the Indian coal seams appear to be impregnated. This is a considerable drawback to the storeage of Indian coal, but with proper care I do not think that it should be looked upon as an insuperable impediment. The one great thing in this case is to have proper shelter for the coals so as to keep off moisture; and if a free current of air could be maintained through the mass of coal, the danger of spontaneous combustion would be considerably lessened, if not wholly averted. In order to maintain this, however, it is clear that only large blocks of coal must be stacked, the small coal being removed from the mass either by screening at the depôt, or by such other means as may be most convenient, as by stacking only the large coal, there will be left a free passage for the circulation of air throughout the mass. This expedient, however, can at the best be only looked upon as a temporary preservation from ignition, as the coal, from the softness of its nature, will surely begin to disintegrate before long, and fill up the air channels with small dust, whereupon it may be anticipated that fermentation would soon commence, ending in spontaneous combustion. The true remedy must therefore be, not only in storing the coal as carefully as possible in the first instance, but in taking care that the depôts have not more coal placed in them than may be necessary for current working purposes; and this will, of course, necessitate their being replenished more often than would otherwise be the case; but, beyond that, it

does not appear that it would lead to any other inconveniences.

Where a high level is practicable at or near a coaling station, a much better system of depositing coals in depôt may be adopted, and it may be carried out to a limited extent even where the railway runs on a level with the country, but where, owing to the existence of a slight falling gradient, a short siding may be constructed running parallel with the main line but on a higher level, this siding being carried either on brick arches, or on timber staging, or on a viaduct composed of brick piers with iron or wooden girders stretched across from pier to pier, or by any other similar means as may be most convenient; the great object being to utilise the bays beneath the siding for the purpose of storing coal. This constitutes, in principle, the chief improvement in the coal depôts of most modern construction, which, however, are usually fitted with mechanical contrivances to a greater or less extent according to the requirements in each case, and the purposes for which the stored coal is intended to be used. One great advantage in this form of depôt is that hopper-bottomed wagons are brought into use, and these are not only the best adapted for most purposes connected with coal traffic, but they are also independent of machinery, such as is required where wagons with end or side doors are employed, and, it is believed, their use is attended with more economical results with regard to the breakage of coal, as they are also certainly more expeditiously emptied than any other kind of wagon, and so most economical in point of time. The only objection which can be raised against the use of the hopper-bottom wagon is that it is slightly heavier, in proportion to the amount of coal that it can carry, than any other kinds of wagon, and consequently where they are used a slightly larger proportion of dead or unpaying weight has to be carried than where other kinds of wagon are employed, but this would appear to be more than compensated for by the several circumstances above mentioned, wherein the hopper-bottomed wagon is preferable to others.

The most simple form of depôt of the improved type consists merely of a siding, carried on a high level, of the description given above, the bays communicating with the wagons by means of traps between the rails, through

which the coal is allowed to fall from the wagon into the store beneath, and it is taken out again through communications from the lower level beneath the arches or bays. These bays may thus be used for the storeage of coal, or merely as a means for the transferring of coal from the railway wagon into a cart, or other receptacle, for the purpose of being conveyed elsewhere. Where the drop is but small, a cart may be backed in directly beneath the trap, and the coal be allowed to fall at once from the wagon into it; but where there is a fall of any extent this would be impracticable, and the coal must then either be allowed to fall direct to the bottom of the depôt first, and then be raised again by hand, or some sort of inclined shoot must be employed to ease the fall of the coal. Where space will admit of it, the latter is by far the preferable plan as it causes less breakage, and is attended with less labour than by the former plan. The use of an inclined shoot at the depôt naturally suggests the feasibility of combining the means for screening the coal without the addition of any extra appliances beyond the introduction of bars in the shoot in place of a plain surface throughout; and these bars may either be made to extend for the whole length of the shoot, or along a portion of it only, as circumstances may appear to render advisable. It will, however, be found advisable generally to place the bars in the lower part of the shoot, leaving the upper portion, on which the coal first falls from the truck, plain, as in that case the coal will not suffer so much from breaking in the fall as it would if it were received on the sharp edges of the screen-bars. Where screens are thus used the small coal passes through the bottom of the shoot, falling into the space beneath, whilst the round coal falls from the mouth of the shoot into any convenient receptacle placed there for the purpose with the view of at once removing it, and carrying it away in sacks, or otherwise, for sale or immediate use. At some of the depôts, especially where there is a deep fall for the coal, a hopper is constructed at the top of each shoot capable of holding two truck loads of coal, and the shoot communicating with the bottom of the hopper allows the coal to fall down the screen as fast as may be necessary, a special arrangement being provided—which will

be presently noticed—for preventing it from running down too rapidly. Where speed is an object, the introduction of the hopper top to the shoot is an advantage, as it admits of two lines of rail being placed in communication with each shoot, and two truck loads of coal can consequently be emptied into it at once. At the mouth of each shoot is generally placed one of Poupard's patent sacking apparatuses, and sometimes his form of screen is also used, but it does not appear to be much in favour, owing to its liability to break. Poupard's screen consists of a cast iron grid, the bars of which are in the form of a continuation of reverse curves, thus:  joined together at intervals with cross-bars. The screen is cast in one piece, so that, in the event of a breakage taking place, the whole screen has to be removed, and a new one put in. The more favourite sort of screen is one consisting of straight iron bars, cast separately, with projecting distance-pieces on one side, so as to maintain the screen at the proper gauge, thus:  These bars all fit into a suitable fixed iron frame-work, and, in the event of one of them becoming broken, it is easily taken out and replaced with the least possible delay. These screens are usually from 7-16ths to 5-8ths of an inch between the bars, the wider space being usually only adopted for best house coal.

When the depôt apparatus for sacking and carting away coal is on an extensive scale, constructed with the view of removing the largest amount of coal in the shortest time, some arrangement is necessary to prevent the coal from passing down the shoot more rapidly than it can be taken away. For this purpose, one of two arrangements is usually adopted. The first is to hang what are known as "grappling irons" from the top of the mouth of the shoot, and which, swinging on a hinge, fall upon the mass of coal, holding it back on the shoot. These are raised as more coal is required to pass down by means of a lever communicating with the mouth of the shoot by a long handle, thus placing it under command by the man at the bottom. The objection sometimes raised to the use of these grappling irons is that they break the coal, and they are therefore not now in any very general use.

The second arrangement is to hang a wooden door bound with iron, of a less width than the depth of the shoot, and so fixed that it will, when down, fall at an angle, with its lower end resting in the direction of the top of the shoot. This answers every purpose for holding the coal back, whilst at the same time it does not injure it by breakage. Where sacks are employed for carrying away coal from the depôts, Poupard's sacking apparatus is in almost universal use. It is attached to the mouth of the shoot, and consists of a weighing machine, fixed at a proper distance below the shoot to accommodate the length of the sack, whilst the mouth of the shoot is fitted with an iron door, which is raised upwards, being attached at one end to the shoot by a horizontal pin on which it turns, and at the other end a short projecting arm falls into a catch when the door is closed. When a sack has to be filled, one man holds it up on the weighing machine, whilst another, after having let down a sufficient quantity of coal from the upper part of the shoot, raises the door just mentioned, allowing the coal to run directly into the sack until it is full. As soon as the weighing machine registers that the full weight of coal is in the sack, the iron door at the mouth of the shoot is brought forcibly down, and stops any further supply from falling out until the full sack has been exchanged for an empty one. At the best laid out depôts these weighing machines are placed at such a height above the ground that they are about level with the floor of the ordinary coal cart, which is backed into the depôt so as to come almost close up to the weighing machine. By this arrangement the labour of lifting full sacks of coal into the cart is reduced to a minimum, and the coal is carted away with the greatest possible expedition.

Under the same bay, and at the back of the screening and sacking apparatus, the depôt for storing coal is placed. This generally consists of a portion of the arches, over which the lines of rail are carried, divided off for the purpose, and having openings at the top, between the rails, through which the coal is dropped direct from hopper bottomed wagons. The depth of the fall varies according to circumstances and local peculiarities; but, even in the most favourable cases of a short vertical fall, the destruction of coal must be very great. This might

be in some measure remedied by passing the coal down shoots into the storing depôt, but this again would necessitate the occupation of more space, which might be inconvenient in crowded localities in the vicinity of large towns. A still better arrangement would be to lower the truck bodily into the depôt, which might easily be done by means of a traverser, fitted with a counterbalance arrangement and friction breaks, and so adjusted that, upon releasing the breaks, the full wagon would descend upon a skeleton platform to such a depth as would admit of the coals falling only from the least height that would admit of the hopper doors being fully opened. Upon emptying itself the wagon would be brought up again to the rail level by the action of the counterbalance weights; it would then be run off to the siding for empties, another full wagon at once taking its place upon the counterbalanced traverser.

From returns collected by Mr. Plimsol, at the Cambridge Street Depôt, King's Cross, the average amount of small coal passing through the screens at the staiths, was between five and six per cent., but at the staiths in Walworth Road the loss was as high as nine, and, at times, even eleven per cent. This difference, whilst no doubt partially due to the depth of fall and angle of screens being greater at the latter place than at the former, may also probably be in some measure due to the proportion of soft friable coal being greater in the one case than in the other. At the Shoreditch Depôt, the results of observations taken at two screens, and extending over a period of upwards of a month, with different kinds of house coals, showed that out of a total of 3,057 tons 12 cwt. of coal tipped from the wagons. 229 tons 14 cwt. passed through a screen measuring 7-16ths of an inch between the bars; thus showing an average loss of, as nearly as possible, 7.5 per cent.

The importance of storing coal in well-covered places, so as to protect it from the effects of damp and atmospheric or climatic influences, in the place of stacking it out in the open air, is, apparently, only now beginning to be recognised in this country, and as heat appears to be the one great source of the destruction of coal so exposed, when combined with moisture, the necessity of providing such protection is even greater in India than it is in this

country. Dr. Richters, in a recent communication to a German paper, states his opinion that this destruction of coal by exposure, or the "weathering" of coal, as he calls it, depends upon its ability to absorb oxygen, converting the hydro-carbons into water and carbonic acid. Herr Grundmann, of Tarnowitz, has also recently published elaborate experiments, proving the effects of exposure on bituminous coal to be most serious. Coal which he exposed for nine months lost 50 per cent. of its value as fuel. His conclusions excited such doubts that his experiments were repeated, in connection with Herr Varrentrapp, of Brunswick, who proved by laboratory experiments, that oxidation took place at common temperatures. Three months sufficed to rob coal, kept uniformly at 284 degrees (Fahr.), of all its hydro-carbons. Grundmann proved that the decomposition was the same in the middle of the heap as at the surface, and reached its maximum about the third or fourth week; that half of the oxygen was absorbed during the first fourteen days; that a poor coal in oxygen absorbs it most rapidly; that moisture is an important condition; that coals making, when freshly mined, a firm coherent coke of good quality, make, after even only eleven days' exposure, either no coherent coke at all, or coherent coke of quite inferior quality; whilst, for gas purposes, the coal is also greatly injured.

By referring to Dr. Oldham's report on the "Coal Resources and Production of India," pages 20 to 22, it will be seen that the composition of Indian coals, from the different known beds, showed an average of 52.2 per cent. of carbon only; whilst an assay of five specimens of English coals, saleable in the Calcutta market, showed them to contain from 63.8 to 74.6 per cent. of carbon; the average of them all being 68.10 per cent.. In this respect, namely, the proportion of carbon present in the coal, it is further stated, "that the very best coal of Indian "fields only touches the average of English coals." In the third report on the coals suited to the steam navy, it is shown that the mean composition of average samples of Welsh coals varies from 71.08 to 90.94 per cent. of carbon; of Newcastle coals, from 81.85 to 86.96 per cent.; of Lancashire coals, from 68.72 to 82.61 per cent; and of Derbyshire coals, from 77.49 to 81.93 per cent. of carbon.

Of Indian coals, the poorest in carbon was taken from the Godavery river, which specimen gave only 23 per cent. of carbon, and the richest was taken from Mollichooan, in the Kurhurbali coal field, which showed as much as 73.1 per. cent. of carbon. If Grundmann is correct in his theory that a poor coal in oxygen absorbs it most readily, it is probable that besides being poor in carbon the Indian coals are also, as a rule, poor in oxygen, and this may account for their rapid deterioration upon exposure to the atmosphere.

Taking the above circumstances into consideration, it seems highly desirable that all depôts for coal in India should be constructed upon the most approved principles, with the view of protecting the fuel as much as possible, from the effects of the atmosphere. A still further argument in favour of protecting Indian coal from climatic influences is that so many of the native coals are strongly impregnated with iron pyrites, which, from their decomposition when brought into contact with moisture, are very liable to produce spontaneous combustion. These pyrites should, as far as possible, be picked out of the coal by hand at the pit's mouth, as is done in the Newcastle coal district, where pyrites also are found in quantity in some of the coal-beds. By this means a great source of danger would be removed from the coal itself, whilst at the same time the fuel obtained would be more valuable.

These iron pyrites might also be utilised in the promotion of an important industry, in the same manner as they are employed in Yorkshire and on the Tyne in the manufacture of copperas and of sulphuric acid. "For " this purpose they are exposed in wide-spread heaps to " atmospheric action, and the result is the conversion of " the sulphur into sulphuric acid, which, combining with " the iron, forms the sulphate of the protoxide of iron, " which is dissolved out and re-crystallised. The same " result may be obtained more quickly by roasting the " sulphur ores." "Vitriol is formed in these stones " by exposing them a long time to the action of the " air and moisture, or by torrefaction in open air, and subsequent exposure to its action, which operation, in some " cases, must be often repeated, according to the propor-" tion of sulphur and the nature of the earth; the cal-

" careous pyrites are those in which it is most easily " formed, and they effloresce the soonest. Good pyrites, " when properly treated, yield about two-thirds of their " weight of vitriol."*

The foregoing remarks are, however, somewhat of a digression from the subject now more immediately under consideration; but they have been introduced here advisedly with the view of pointing out, not merely that the pyrites so often present in Indian coals may be converted into a profitable source of revenue, but more particularly to show the extreme importance of providing efficient protection for those coals which contain within themselves such powerful elements of self destruction. It has already been pointed out that iron pyrites have a tendency to originate spontaneous combustion, when mixed with bituminous coal in a comminuted state; this, however, only takes place where the mass is exposed to the free action of the atmosphere; and hence the importance of reducing that tendency to a minimum, by providing above ground such protection as may be practicable, by the construction of suitable storing places wherever the coal is required to be deposited in depôt.

The arrangement of the lines of rail, leading from the railway to the depôt, must of course, in a great measure, be dependent upon local conveniences, and will thus differ in various localities. In some places the different storing bays are arranged in a line, over which a single line of rails passes, there being another parallel line or lines, to take away the empty trucks, a traverser being placed at one end of these lines so as to remove the empty trucks to their proper line, which should be laid at a gentle incline, say of 1 in 100, so as to enable them to run down of their own accord, and make room for others until a sufficient number may have been collected to form a train, to be taken away by a locomotive. The inconvenience of this arrangement will be at once apparent, and does not therefore need to be pointed out. The

* Ure's Dictionary—"Coal Brasses"—"Pyrites." Further very interesting particulars relative to the utilization of products obtainable from Iron Pyrites, have recently been given by Professor Olding, F.R.S., in his lecture at the Royal Institution, on the "Utilization of Waste."

better, and more generally adopted method is to place the lines of rail at right angles to the line of coal bays, with a traverser running parallel to the coal bays at either side of the cross lines. By this means the coal wagons may be passed over the bays, emptied, and returned again to the main line siding to be formed into trains of empties, with the least possible delay. In some places the wagons are hauled on and off the traverser, and the traverser itself is worked by horses; but at the last new depôt, near the "Elephant and Castle," a great improvement and saving has been effected by the introduction of a steam traverser, which is also fitted with a capstan, likewise worked by steam, and so fitted with clutch couplings that either the one or the other may be worked at pleasure, and the motion may be changed, from the capstan to the wheels of the traverser, without stopping the engine.

The whole arrangement should be covered over by a light iron roof, so as to protect the coal from the weather, and to afford a covering to the men employed in discharging the coals from the wagons into the depôt.

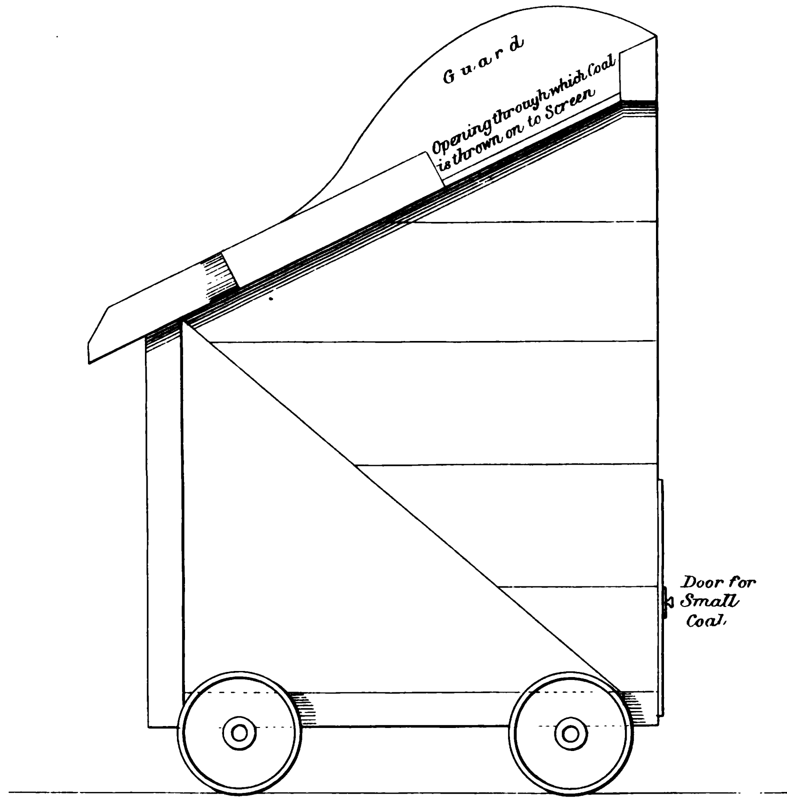
Allusion has been made at a former page, to the very questionable advantages of screening coal at the pit's mouth, or, indeed, anywhere excepting at the last place from whence it issues before being brought into actual use. This objection, it must however be stated, refers only to coal that is taken out of pits worked on the "separation" principle. Where the coal is sent up altogether it is undoubtedly desirable to remove some of the dust at the pit's mouth by screening, otherwise the proportion of useless small taken away would add considerably to cost for carriage. The practice of screening coal at the pit's mouth dates as far back, it is believed, a the time when duties were first imposed on coal, such duties being leviable only on round coal sent from the colliery, the small taken out at the pit's mouth not being liable to a similar taxation. In general, however, since the repeal of the duty has left it to the discretion of the coal dealer whether he will send large or small coal to market, or both together, the use of screens has been optional. In some places, as has been already pointed out, the screens are much narrower than at others, the width in each case being determined by the lessor in

districts where he claims no royalty for small coal. In other districts, where the practice is for the lessor to claim upon all that is brought up, whether large or small, the width of the screen is fixed by the lessee to suit the market.

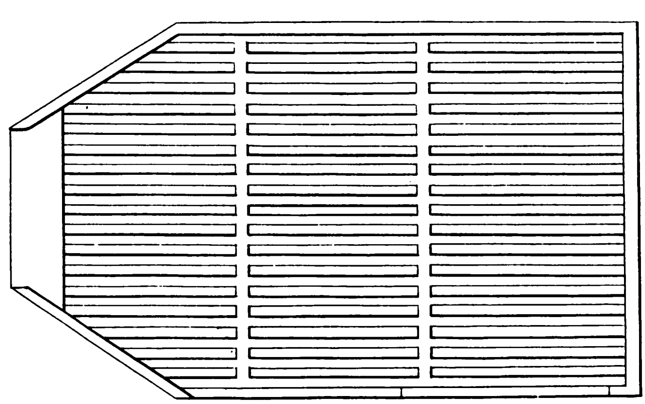
At depôts where the special arrangements, described in the preceding pages of this chapter, are not provided, and where recourse is generally had to simple stacking of coal in the open yard, screening has to be performed by hand, and in many instances a common hand sieve is used for the purpose. The Clay Cross Colliery Company have, however, recently introduced a very convenient portable coal screen, by means of which the work can be carried on more expeditiously. This consists of a wooden framework mounted on four wheels, at the top of which is placed the screen at a suitable angle, and having raised sides, excepting at a point near the upper part where a space is left through which the coal is thrown by spades on to the screen. Beneath the screen is a hopper shaped box, into which all the small coal falls, a suitable door being placed at the bottom for the purpose of emptying it when full. The screens are of cast iron, and in one piece; the distance between the bars varying from three-eighths to five-eighths of an inch according to circumstances. The height of the screen is six feet at the upper end, and the mouth of the shoot from the screen is four feet above the ground, or just sufficient to admit of an ordinary coal sack being conveniently filled direct from the screen.

The illustrations which accompany this chapter are as follows:—1. An enlarged plan and section of the modern type of coal staith; and 2. A plan of the Clay Cross Colliery Company's hand screen, drawn from memory, but which quite sufficiently illustrates the principles of its construction to make the foregoing description fully intelligible. These illustrations form Plates Nos. VII and VIII.

PORTABLE SCREENING APPARATUS.



SIDE ELEVATION.



PLAN OF SCREEN.

Scale 2/3 Inch - 1 Inch.

Metchim & Son, Parliament St.

CHAPTER V.

SHIPMENT OF COAL.

Early construction of places for lading Coal—Staiths—Meaning of the word "Staith"—Three modes of Shipping Coal—Shipping by Keels; by tubs on boxes; and by the spout—Storehouse near the shipping place—Importance of protecting Coal—Methods of shipping Coal on the Tyne—The spout chiefly used—Coal not screened as a rule on the Tyne—Waste of Coal caused by screening—Doctor Hutton on the space occupied by Coal—Estimates of waste between the colliery and the ship—Small made by fall into ship's hold—Various expedients for protecting the Coal from breakage—Shipping by means of tubs—Coal staiths at Swansea—Shipping Coal from boxes—Hydraulic drops and shoots—Shipping Coal with platforms—Counterbalance shoots at Cardiff—Description of counterbalance drops and shoots—Anti-breakage box—Hydraulic shoots for low level lines in use at Newport—Speed with which Coal can be shipped—Staiths at Penarth—Loading barges with Coal—Loading from hopper bottomed wagons—From side-door wagons—From wagons with end doors—Hand tipping apparatus—Their use limited to certain sized wagons—Nixon's steam tipping machine—Unloading from ships—Machinery not generally used for this purpose abroad—Floating Coal Depôts on the Thames—Machinery for unloading vessels by hydraulic cranes.

It is not necessary to commence this chapter with any preliminary remarks as to the importance, or otherwise, of the subject treated therein. Shipment of coal, in the widest sense of the word, is not likely to attain to any great magnitude in India for many years to come; but in its lesser sense, namely, where coal is conveyed by canal or river, the shipment of coal into barges may have to be resorted to in many localities where railway accommodation is wanting, whilst the means of water carriage is available.

In the "History of Fossil Fuel, &c," it is stated that "places for the convenience of lading coals from the "bankside into keels,* were no doubt constructed at a

* Keels are barges employed at Newcastle to carry Coals from the land to the ships. Formerly they held twenty chaldron of 53 cwt. each.

" very early period; and in the chartulary of Tynemouth " Monastery, 'staithes' are incidentally mentioned as " early as A.D. 1338; there were, probably, however, " nothing more than small wharves, or platforms, as in a " grant made by the Bishop of Durham, in 1575, the " lessee of certain mines is to have 'sufficient way leave " to the water of Tyne, where he was to have *a staith to* " *lay the coals on.*" The word staith is plainly derived from the Anglo-Saxon staVe, *ripa*, *littus*, *stationavum*. At Hythe, in Kent, the landing-place is called the stade, and at Whitehaven, they are called steers.

In the Minutes of Evidence attached to the Report from the Select Committee of the House of Lords, appointed, in 1829, to take into consideration the state of the coal trade of the United Kingdom, three modes of shipping coal are described as follows, at page 35:— " The first or original plan is by carrying them down the " river from the staiths, which are depôts in which coals " are placed when they come from the collieries by " wagons, to be ready to be loaded into keels. The next " mode is by what are called tubs or boxes, which are " loaded from the wagons, and pass down in bulk to " the ship, where they are by machinery hoisted and put " on board the vessels. The third and most approved " mode is, by what is called the spout. The vessels go " down to a sort of stage, with a spout to it, and the " coals are at once discharged into the ship." Before describing the different mechanical appliances in use at the present day for facilitating the shipment of coal, it may not be out of place to give here the following extract from an old Encyclopædia Edinburgh, which appears under the head "Coalries," as it applies with great force now to the necessities of coal in India, and more particularly of native coal:—" Where the pits are situated " at some considerable distance from the harbour, it " becomes necessary to have a storehouse near the " shipping place, where the coals may be lodged until " the lighters or ships are ready to take them in. The " wagon-way should be made into the storehouse, at " such a height from the ground as to permit the coals " to run from the wagons down a spout into the vessel; " or else to fall down into the storehouse, as occasion " may require. This kind of storehouse is well adapted

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"to dispatch, and saving expense; for a wagon load of "coals may be delivered either into the storehouse or "vessel instantly, with very little trouble; and if the "coals were exposed to the effects of the sun and rain, "they would be greatly injured in their quality, but "being lodged under a storehouse, they are preserved."

For reasons already given, it is not purposed to dwell at any length upon the various methods adopted for the delivery of coal into ships for transport by sea. As will be briefly explained further on, many methods are at the present day in use; the one now in use at Sunderland is shown on Plate IX., which is copied from illustrations accompanying a paper, "On the Tyne Docks at South Shields," read by Mr. T. E. Harrison before the Institution of Civil Engineers, on the 3rd May, 1859. The plan now almost exclusively employed at Sunderland and South Shields is the spout leading from either side of a jetty, as shown in the above plan, the only modification being that an additional incline is placed near the top, and directly under the wagon, so as to reduce the vertical fall of the coal in the first instance. It is not the practice on the Tyne to screen coals upon their passage from the wagon into the ship, although it is sometimes required to be done, and the spouts are therefore furnished with a set of bars for a portion of their length, which can be used for that purpose when desired; but mostly these bars are closed by a sheet iron door beneath, which renders the shoot in effect as though it possessed no screen at all. The destructive effects of screening have already been briefly referred to, and the advantage that would follow the discontinuance of the practice as it is now carried out, especially in South Wales, insisted upon. Mr. H. Taylor, in his evidence before the Select Committee of the House of Lords in 1829, bore evidence to the same effect, stating that very great waste of coal was occasioned in the North by screening, and when asked, "Is not the destruction of small coal, which has been referred to, to be attributed to the necessity of screening?" his reply was, "Certainly it is occasioned by the screening." In this respect, however, the advantage of the shipowner is somewhat opposed to that of the coalowner, for the larger the coal is and the freer from small, the less space does it occupy, as proved by Dr. Hutton,

who states that, "if one coal measuring exactly a cube " yard (nearly equal to five bolls) be broken into pieces " of a moderate size, it will measure seven coal bolls and " a half; if broken very small, it will measure nine bolls; " which shows that the proportion of the weight to the " measure depends upon the size of the coals."

No one who has watched the loading of a vessel with coal by means of a shoot or spout can for one moment doubt that the latter becomes considerably depreciated by breakage immediately it falls into the hold of the ship. According to the calculations of one gentleman whom I consulted on the subject, the waste between the colliery and the ship was equal to about five per cent.; whilst the loss in small upon unloading a cargo could not be averaged at less than from fifteen to twenty per cent. Another gentleman, engaged in the coal shipping trade in South Wales, estimates the amount of small made between leaving the colliery and arriving at the ship, when double screened at Cardiff, at from eight to eight and a-half per cent.; the amount of small made by the fall into the ship and by unloading being about twenty per cent. To save the coal as much as possible in this stage, various expedients have been adopted. The first notice on this subject which appears in any of the documents consulted, is in the evidence before the Lords' Select Committee already referred to, where, at page 23, the following description is given by Sir Cuthbert Sharp, of the mode of shipping coal in the North by means of tubs:—" Tubs are used on the river to prevent, as much " as possible, the breakage of the best coals. They are " simply wagons without wheels, each containing fifty- " three hundred weight, or one Newcastle chaldron; but, " like the wagons, they are not bound to this same " quantity, but they must be a certain proportion of a " chaldron. Eight of those are placed in a keel, and " go to the vessel, and by a mechanical process each " tub is lifted on board the vessel, and placed immediately " over the hatchway of the hold, when the trap-door is " loosened, so that the coals are as little broken as pos- " sible." A somewhat similar plan to this is at the present day adopted by Messrs. Corry and Yeo, at Swansea, who send some of their coal down to the port by canal in boxes placed on barges. These boxes are

raised from the barge by one of Stothard and Pitt's steam cranes, and swing directly over the hatchway of the ship, and are emptied in the manner above described.

Most of the coal staiths at Swansea are supplied with Sir W. Armstrong's hydraulic drops, or with his hydraulic shoots. The former are fitted with jibs, and are employed to ship coal from the boxes, which are sometimes brought down on wagons especially constructed for the purpose. In most cases these boxes are raised, jibbed out, and lowered over the vessel's hatchway, and withdrawn again when empty, entirely by hydraulic power; but sometimes a counterbalance weight is employed alone for the raising of the empty boxes. The hydraulic shoots may briefly be described as follows:—The full wagon is run on to a stage at the top of the shoot, and as soon as it is fixed by a scotch-block, the rear end of the stage is raised, or the front end falls, as the case may be, so as to incline the wagon and cause the coal to fall out at the end door (with which these wagons are all fitted), on to the shoot. The stage is then brought to a level position again and the empty wagon is run off. In connection with these staiths there are also often employed what are called anti-breakage boxes. These are used at the commencement of loading in order to form a bed of coal at the bottom of the vessel under each hatchway, in order to break the fall of the rest of the cargo. These boxes are filled with coal and lowered by means of a jib down into the hold and there emptied. Another system sometimes employed for the same object is to load the vessel with a series of platforms under the hatches (consisting of planks of from one inch to one and a quarter inch thick), nine feet long by seven feet broad, and placed six feet apart in height. These also facilitate very greatly the unloading of the vessel, which is also thereby effected with a less degree of breakage.

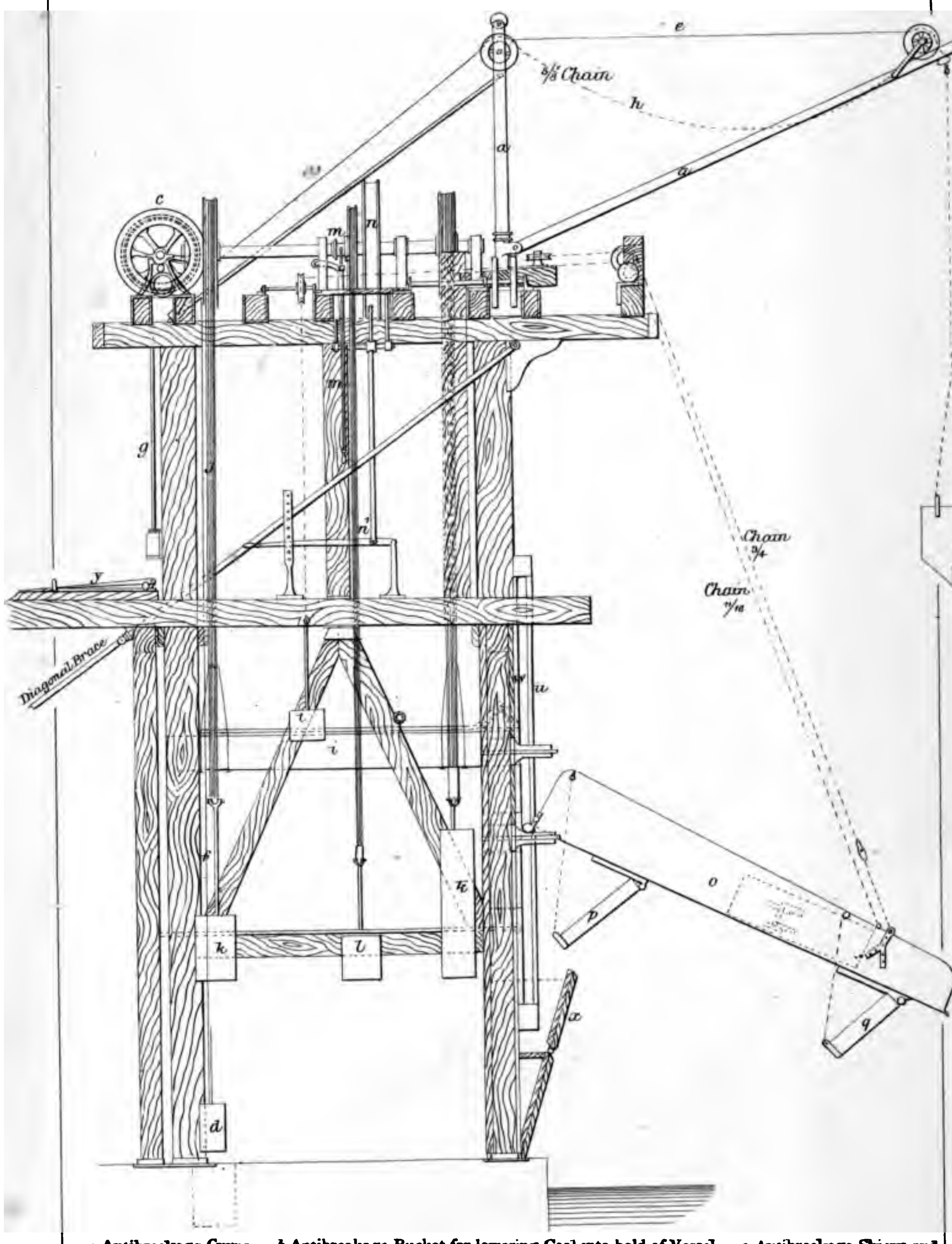
At Cardiff, counterbalance shoots are principally employed. In these, all movements are regulated by means of counterbalance weights, but in other respects they are very similar in action to the hydraulic apparatus above referred to, and they are capable of performing the same work, with the exception of unloading, for which purpose hydraulic drops may be used. The principle

of the counterbalance drop and shoot will be understood by reference to the accompanying illustration (Plate X.). The balance weights are restrained until they are required to be brought into use by means of friction break drums, the break being easily put on or removed by the simple action of levers. In the use of these machines the anti-breakage box is lowered by the weight of the box itself, which when full is heavier than the counter-balance weight with which it is connected by means of a chain, but when empty the weight overbalances the box, and it is thus lowered and raised quite automatically so soon as the break is removed. The balance table at the top of the shoot, on which the full wagon is placed, is hung on trunnions at a point behind its centre, and as soon as the wagon is run on, and the break is released, the fore part falls by reason of the weight, thus tipping the wagon, and causing the coals to fall out down the shoot. Whilst the truck is emptying the breaks must be put on, so as to retain it in a proper position until the coal is all out; but as soon as that is the case the break is again removed, and the counterbalance weights attached to the table, being heavier than the effective weight of the wagon, cause the table to assume its former horizontal position, where it is again held by breaks until another wagon is ready to be emptied.

The machines with shoots, above described, are only applicable where the wagons can be brought to the quay side on a high level. The counterbalance drop also is only adapted for a high-level service, but the hydraulic drop may be used where there is a low-level line. At the East Bute Dock at Cardiff, where the rails are on a level with the quay wall, hydraulic shoots have been adapted to the circumstances of the situation. In these the rocking table on which the coal wagon is placed rests normally on the same level as the rails leading to it. Beneath it are two hydraulic rams, the cylinder of one of which is fixed, whilst the other is attached to the framework of the table itself. By means of the former the table is raised, with the coal wagon upon it, to the level of the top of the shoot, after which the second cylinder is brought into action, and gives the necessary angle of inclination to the table to cause the coals to fall out of the

COUNTER-BALANCE COAL TIPPING APPARATUS. CARDIFF.

PLATE. X.



a Antibreakage Crane *b* Antibreakage Bucket for lowering Coal into hold of Vessel. *c* Antibreakage Shieve and Breakwheel for Bucket also on same Shaft. *d* Antibreakage Balance Weight. *e*, *f* Antibreakage Wire Rope for Balance Weight. *g* Crab for raising Jib of Antibreakage Crane. *h* Chain to prevent Jib from falling too low when in use. *i* Tipping Cradle. *j* Wire Rope from Tipping Cradle to Balance Weight. *k* Balance Weight for Tipping Cradle. *l* Extra Balance Weight for 10-ton wagons. *m* Clutch for throwing extra weight out of gear. *n* Break Wheel for Tipping Cradle. *n'* Lever of Break Wheel for Tipping Cradle. *o* Shoot. *p* Shoot Screen for receiving small coal screenings. *q* Shoot Screen for receiving small coal screenings on deck. *r* Wing to prevent coal falling too fast into hold of vessel. *s* Weight for Heel of Shoot. *t* Weight for Point of Shoot. *u* Crab for raising Heel of Shoot. *v* Crab for raising Point of Shoot. *w* Rack and Guide for Heel of Shoot. *x* Wing Board to prevent small coal screenings falling into dock. *y* Lever for setting catch on Cradle, to prevent it lowering when the wagon first enters upon it, also for stiffening it.

Metchim & Son, Parliament St.

wagon. These lifts are also exclusively in use at Newport, where the coal all arrives at the docks on a low level. By these machines as much as thirty wagons, each holding ten tons of coal, can be tipped in one hour, but this speed is not usually attained. No horses are employed to throw the wagons on to the lifts, but they are moved off and on by means of hydraulic capstans.

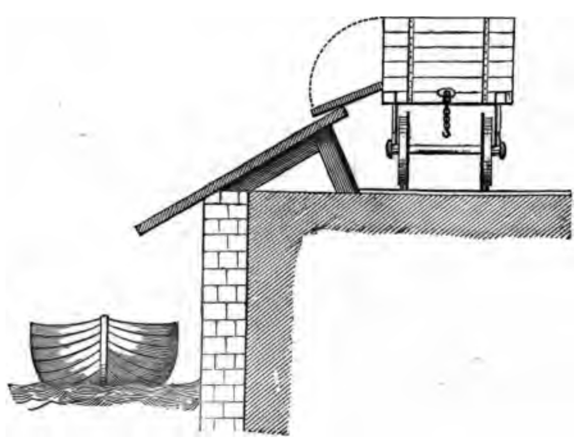
The speed with which coal can be shipped from the counterbalance shoots is regulated very much by the trimmers on board the vessel being loaded, but under exceptionally favourable circumstances the Taff Vale Railway Company have shipped from one of their counterbalance staiths at Penarth fifty wagon loads of coal, each holding seven tons, in one hour with a working staff of seven men.

There are various arrangements in use for loading barges with coal, and as these are more likely to be of use in connection with the coal trade in India, it is proposed to enter into fuller detail regarding them than has been thought necessary in the case of appliances for the shipment of coal for transport by sea. These arrangements vary with the form of the wagon in which the coals are brought to the water-side, some of them being on the hopper-bottom principle, whilst others have side doors and end doors respectively.

The simplest plan of loading from hopper wagons may be seen at the basin belonging to the Great Northern Railway near King's Cross. This consists merely of a timber staging run out into the water, upon the top of which rails are laid for the coal wagons, spaces being left between them for the coal to fall through into the barges which are moored beneath. In this case the height of the staging should be only just sufficient to admit of the free passage of the barges beneath, so that the fall of the coal may be as small as possible. Where the line of railway is at a high-level above the water, hopper wagons are sometimes emptied into large iron hoppers placed beneath the rails, and having shoots from their lower end, down which the coal passes into the barge beneath.

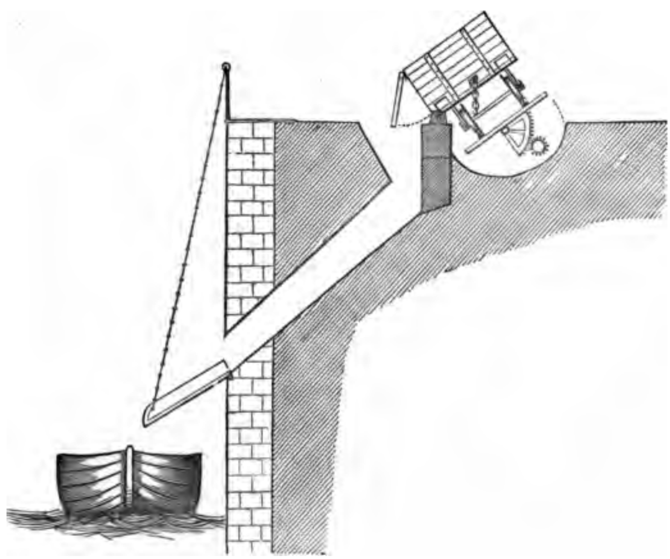
For side-door wagons, the simplest arrangement for emptying coal wagons into barges, is to be seen at the

Chelsea basin on the Thames, where the Great Western and the London and North Western Railways have their principal coal shipping depôts. Along either side of the basin there is a long wooden incline hanging over the quay wall. It is formed of three inch planking nailed on to a dwarf wooden framework, and covered on its upper side with sheet iron. The shore side is raised to a height so as to be level with the floor of the wagons, whilst the other side projects over the quay wall a short distance, so as to clear the coal from falling into the water between the barge and the wall of the basin, as shown in the accompanying sketch. The coal is then



shovelled out by hand. The cost of loading by this means is about two-pence per ton. It is at best but a clumsy method, very slow in operation, and must cause a great deal of breakage. The side-door wagon is, however, by no means well adapted for the purpose of carrying coal for shipment, in which respect it is very much inferior to any other sort of coal wagon. At the Great Northern Coal depôt, the following arrangement is in use for emptying coals into barges from side-door wagons:—An iron hopper is placed at a short distance on one side of and below the level of the rails on the siding, which communicates by means of a spout or shoot with the mooring place for barges. A short piece of the railway on the siding, of sufficient length to hold one coal wagon, is attached to a rocking frame, which is

worked by means of a hand crab, which puts in motion a pinion shaft gearing into a toothed segment. The wagon is by this means tipped over sideways, the buffing ends of its frame falling on to stop posts to prevent it from going beyond its centre of gravity, and thus falling over. The coal is then shovelled out and falls into the hopper, and so down the spout into the barge beneath. The accompanying free-hand sketch will give a sufficiently correct idea of this method of shipping coal



into barges. As it is not one to be commended, and can only be looked upon as a makeshift to suit certain exceptional circumstances, it has not been thought worth while to obtain any more correct drawings in illustration of it.

Next to the hopper wagons, those with end doors are the most convenient for coal loading into barges, as well as for shipping purposes. As these are also most generally used, a better class of machinery has been introduced for them than for those with side doors. On the present occasion two machines only will be noticed, which appear to be very well adapted for the purposes to which they are applied. One of these is a hand worked machine, and is sufficient where only a moderate trade exists; and the other, worked by steam, is capable of

meeting the requirements of a tolerably large boat coal traffic.

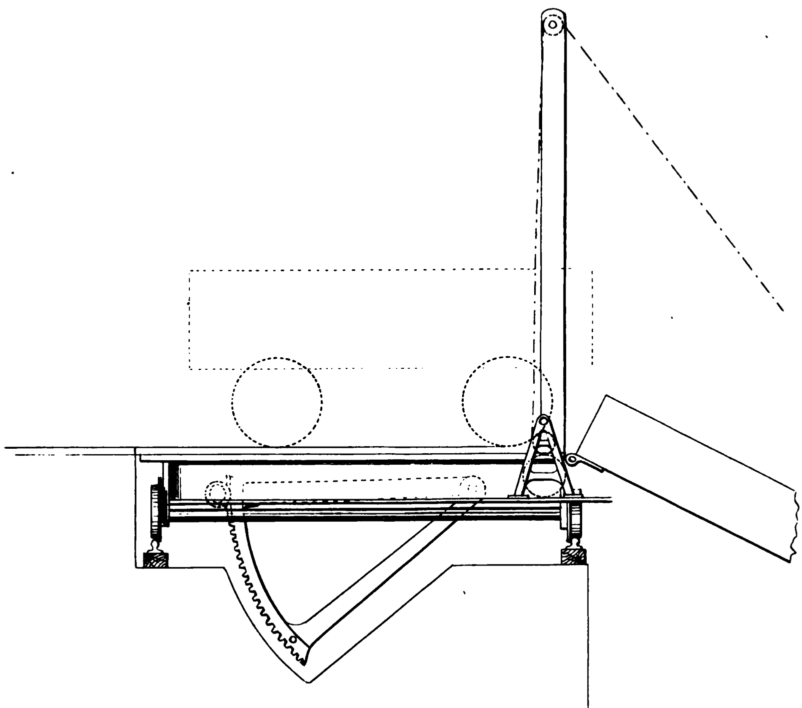
Tipping machines of the former kind may be seen in use at Chelsea Coal Basin and the Great Western Depôt at Brentford. It is not necessary to give any illustration of them here as the principle upon which they work will be sufficiently understood by reference to the drawing (Plate XI.) of the steam tipping apparatus; the general principles of both being somewhat similar, although they differ in detail, the extent of which difference will be made clear by the following description.

The hand machine consists of a revolving table, with rails for the receipt of the wagon on the top, whilst below there is a toothed segment and pinion gearing communicating with a hand winch, the latter being placed on one side of the table above ground. The end of the revolving table is about flush with the quay wall, which is here cut away, and beyond it, overhanging the water, is a hopper to receive the coal from the wagon, whence it passes by means of spouts to the coal barge below. The table is so balanced that as soon as the wagon full of coal reaches the end of it, it is overturned to a sufficient extent to admit of the coal falling out, by the front end falling and the hind end rising. It is prevented from going over too far or too fast by a friction brake which can be put on or off at pleasure by the man in charge of the machine. As soon as the coal is all out the weight on either side of the centre on which the machine revolves is nearly equalised, and the table is readily brought round again to a horizontal position by means of the hand winch, and the empty wagon is run off. These machines, are, of course, made for wagons of a certain size and weight. If other sized wagons are used, the balance is of a necessity destroyed, and the automatic property of the machine is lost. It can then only be worked by means of the hand winch, and at a considerable expenditure of labour.

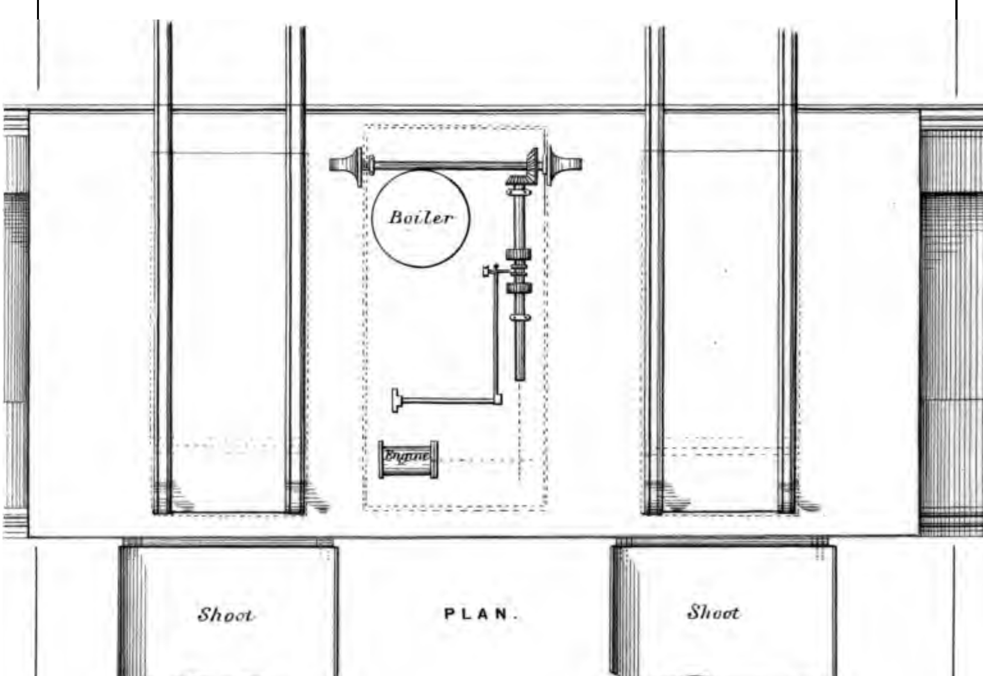
These defects are wholly obviated by use of the steam tip above referred to, the properties and nature of which will be better understood from the following detailed description. This machine has been designed and patented by Mr. John Nixon. An illustration of it will be seen on Plate XI., from which it will be seen that the

PLATE XI.

COAL TIPPING APPARATUS.



END ELEVATION.



PLAN.

Metchim & Son. Parliament St.

tipping frame and shoot are mounted on a carriage, or traverser, which also carries the steam engine by which the tipping frame is worked. The machine at Chelsea Basin has two revolving tipping frames, with the engine house between them. At the front end of each tipping frame is a shoot, hinged so as to be capable of being adjusted to suit the height of the barge to be loaded, which leads the coal into the barge. The whole apparatus is mounted on wheels, and traverses a platform about sixty or seventy yards in length, running parallel to the river side, thus enabling three barges to be moored alongside at one time. Leading to the tipping apparatus are four lines of rail, two of which contain the trains of full wagons, and the other two receive the empties after having discharged their contents into barges ; the distance of the rails apart being, of course, equal to the space between the two tipping frames of the machine. The arrival lines are each provided with a turntable, in case the wagons should be brought up wrong end on. A capstan mounted on the frame, and driven by the engine, is employed for drawing the wagons on and off the tipping frames. The engine, which is on the direct acting horizontal principle, is covered in by a wooden hut, so as to protect it from the weather. This engine drives the capstan above referred to, by which the loaded coal wagons are wound forward off the line of rails on to the tipping frame. It also drives a train of gear which actuates the carrying wheels of the carriage, and in this way the carriage with the loaded wagon upon it is traversed along the river wall until it arrives opposite to a barge moored or stranded, as the case may be, alongside the wall. The engine then, by means of a slutch, is put in connection with a pinion gearing into a quadrant on the tipping frame, which is thus rocked so as to tip the coal out of the wagon into the barge. The wagon being emptied, the tipping frame is then brought back, and the carriage is traversed as before until it comes opposite to another line of rails at right angles to the river wall, and on to this line the empty wagon is transferred. The carriage then goes back to the first line of rails for two more loaded wagons, and so the work is carried on continuously. By this means as much as one hundred tons an hour

can be tipped into barges, the cost being 2½ pence per ton.

During all the stages through which coal has to pass probably nothing is more destructive to it than the treatment it has to undergo in the process of being unloaded from ships; no better provision for that purpose being generally available than an ordinary ballast crane, whilst too often even that extent of mechanical appliance is wanting. It might not unreasonably be considered that the present work would be incomplete without some allusion to the unloading of coal vessels. Although it seems hardly probable that the requirements of any Indian port for coal will, for many years to come, be sufficient to justify any heavy expenditure in the construction of machinery for unloading coal brought by sea; yet as the subject of unloading vessels follows naturally upon questions affecting the loading of them, it is thought that some brief description of the great floating coal depôts in the Thames, at which nearly one third of the whole quantity of the coal brought into the river, or about one million tons annually is unloaded, may not be deemed altogether out of place here.

There are at present in use two floating coal depôts moored nearly in mid-stream between Blackwall and Woolwich. The older one of the two was originally fitted as a powerful derrick for raising sunken vessels, but proving a failure commercially for that purpose, it was in 1861 purchased by Messrs. W. Cory & Son, for conversion into a floating coal depôt. This vessel is in the form of an elongated hexagon, 250 feet long by 90 feet wide. The unloading of the coal is effected by six of Sir W. Armstrong's hydraulic cranes, placed three on each side of the vessel, these cranes being all fitted with weighing apparatus, so that the coal can be weighed as it is unloaded. In unloading a vessel, twenty-four men are employed in the hold filling the "tubs" belonging to the cranes; these men working in three gangs, one at each hatchway. The average load of the tubs is 15 hundredweight, and each crane makes, when in full work, three lifts every two minutes, and a 900 ton ship can thus be completely discharged in six hours; and as this represents the work only of the cranes on one side of the floating stage, and there being a duplicate set of

cranes on the other side, at which a second vessel can at the same time be unloaded, the total capacity of this one floating coal depôt for unloading vessels is equal to the discharge of three hundred tons an hour. The coals, after being raised in the tubs by the hydraulic cranes, are discharged into tip wagons, which run along lines laid on the upper deck, or staging, to the shoots at either end, which conduct the coal to the barges. Below deck the derrick is divided into a number of compartments. In one of these compartments is a pair of engines working the pumps which supply water to the accumulators; in another are the boilers; in another are three small benches of gas retorts which supply gas for lighting the whole depôt; whilst the other compartments furnish accommodation for the gas purifiers, for the gas holders, for the two accumulators from which the water is led to the hydraulic cranes, for carpenters' and fitters' shops, and for stores, &c.

The newer depôt, like the older one, has a flat floor and vertical sides, and its shape in plan is, in general respects, similar. From the accumulators on board this depôt the water, besides being supplied to the hydraulic cranes, is conducted also to a pair of hydraulic engines which work capstans, placed one at the bow and the other at the stern, by the aid of which barges can be rapidly hauled alongside, and shifted into place with but a very small expenditure of manual labour. As in the older vessel, there are three of Sir W. Armstrong's hydraulic cranes on either side of the new depôt, these cranes having jibs with a sweep of twenty-one feet; turning as well as the hoisting being performed by hydraulic power. Instead, however, of the tubs raised by these cranes being discharged into wagons running on an upper deck staging, they are emptied into shoots, by which the coals are conducted into the wagons. The three shoots on each side of the vessel are fitted with screens, so that, if required, the coals can be screened before being received by the wagons. The wagons, which are each capable of carrying an average load of eighteen hundredweight, run on the ordinary deck level, the deck being laid with seven lines of rails, of which four lines are worked in connection with the screens on the one side, and three with the screens on the other side. There are no turn-

tables or switches employed for transferring the wagons from one line to another, for which purpose the following method is adopted:—At three places in their length the whole of the lines are intersected by broad transverse passages or roadways, covered with cast iron plating, and between the ends of the pair of rails forming each line, where they abut on these roadways, are angle iron check rails, curved so that they form a guide for the trucks in their passage from the roadways to the rails. The wagons used have wheels running loose on their axles, and with flanges which go inside the rails; and when they are run from the line on to one of the plated roadways they can be easily slewed on the smooth iron plating, so as to enter any line that may be desired. The wagons discharge their coal into the barges through shoots at the ends of the vessel, the wagons on their way to these shoots being passed over weigh-bridges, and their contents weighed.

CHAPTER VI.

"On the Economy of Fuel, and the Utilisation of Slack Coal."

Utilisation of Small Coal—Economical combustion of Coal—Difference between the theoretical and practical value of Coal—Waste of Coal by imperfect combustion—Extravagance in using Coal in large blocks—Proportions of air necessary for perfect combustion—Use of two furnaces desirable—Escape of heated air represents effective force wasted—Use of fire-brick—Superiority of fire-brick to iron as a heat absorbing medium—Difference between radiated and reflected heat—Proper regulation of the supply of air—Results of an over supply, and a deficient supply of air—Slow and rapid combustion of Coal—Thin fires not economical—Results of combustion in a common grate—Admission of air above the fire—Economic burning of gas—Protection of fuel from atmospheric influences—Wood fuel—Relative amounts of heat evolved by the combustion of different bodies—Classification of fuels in order of their value—Quantity of Coal burnt per mile on the London and South Western Railway—Mr. Beattie's Locomotive—Burning pulverised Coal—Paper read by Lieutenant C. E. Dutton, U.S. Ordnance Corps, before the Franklin Institute—Invention by Messrs. Whelpley and Stower, of Boston—Experiments by Mr. Thomas Russell Crampton—Objections to the use of powdered fuel—Artificial or patent fuel—Clay fire-balls—Essentials of good fuel—Bituminous fuels—Silicious fuels—Farinaceous fuels—Process of patent fuel manufacture suitable for India.

Having, in the preceding chapters, stated briefly how, and to what extent, coal is wasted in working and transit, it remains now only to show how the small coal,—which is more generally known as "duff," "slack," or "waste," may be most economically utilised. From what has been already stated, it will be recognised that the utilisation of this small coal in an economical and profitable manner is a question of national importance, amounting, as it does, to at least one-third of the total production of our coal fields, including that which is left below as well as what is brought to bank. Before entering upon the more general question proposed above, it may not be incompatible with the pretension of the present work to say a

few words first on the larger subject of the economical combustion of coal, more especially with reference to the steam producing properties of coal. In doing this, however, I am treading in the path of many far more competent writers than myself, who have already given their matured experiences to the public, and it is only on account of the vast importance of the subject that I presume now to add my quota of knowledge to what has already been published. The vast difference between the theoretical and the practical value obtained from coal in combustion has been fully explained by the Coal Commission in their report, to which reference has already been made in the preceding pages of this work. All failures to obtain the full theoretic value of fuel must be considered as so much waste, and viewed in this light it will be recognised that by far the greater portion of our mineral fuel resources is now wasted in a most extravagant manner, any information therefore that can be published relative to the means to be employed for its more economical utilisation cannot but be viewed as a contribution towards the accomplishment of a vast national economy.

Nothing is more extravagant than to burn coal in large blocks; and this will be at once apparent upon carefully considering the following facts, which may be tested by any one who desires carefully to investigate the matter. If you place a large piece of coal upon a fire, one of the first changes that takes place is an emission of what is called smoke. This is nothing more or less than the emission of the lighter hydro-carbons from the body of the coal, which, under other circumstances, would have formed gas and tar, and the block of coal may thus be considered as a retort charged with heat-producing particles, which latter are allowed to escape unconsumed up the chimney, or flue, but which, if properly consumed, would yield that portion of heat which is now lost in the present imperfect combustion of coal, and it may confidently be anticipated that the introduction of any method that would ensure their being properly burnt would yield a nearer approximation to the attainment of the full theoretical value of the fuel than is, under present circumstances, generally attained. According to recognised theory, a certain

amount of atmospheric air is necessary in order to obtain the perfect combustion of a given amount of fuel, and numberless devices have been projected with the view of obtaining the introduction into furnaces of the proper proportion of air to the fuel to be burnt, but experience seems to prove that this is impracticable without some further means to aid in the accomplishment of the desired object. The greatest economy hitherto attained has clearly proved that two furnaces are necessary for the most perfect accomplishment of the combustion of fuel, each of which is stoked alternately, so that the heated flame of the one shall burn the escaping unconsumed particles of the other, or else the fuel must be burnt under a pressure, which latter is very difficult to effect under ordinary circumstances of steam production. Under the most favourable circumstances a large quantity of heated air escapes up the chimney and represents so much effective force wasted, and the constant aim should be to present as much heat absorbing surface as may be practicable, so as to retain in the fullest manner what is now wasted, and for this purpose fire-brick affords the best medium at present known, and its power of retention of heat depends in a great measure upon its thickness. Different materials absorb heat in varying proportions, but that heat is again given out, thus helping to realise its proper effective force. From experiments made by the author it appears that fire-brick is vastly superior to iron for this purpose, and that after an equal amount of exposure to fire, the brick will ignite a lucifer by simple contact when the iron is comparatively cold. This is no doubt partly due to the increased thickness of the brick, but partly also to the greater absorbing power of the latter over iron. Thus, then, we arrive at a great fundamental principle for the proper construction of furnaces, which should be lined, as much as practicable, with fire-brick, in order to utilise heat from radiation, and not merely from combustion. A polished surface will, no doubt, reflect heat, as it will light, but the difference between reflected and radiated heat will be found to be very greatly in favour of the latter for the following obvious reasons. The capacity possessed by bodies of radiating heat is very dissimilar, and depends essentially on the condition of the surface; in general the surfaces of

the less dense bodies radiate, other circumstances being the same, more heat than the surfaces of bodies possessing a greater density; they have also greater powers of absorbing heat, for it is a well-known fact that the quantities of heat must be proportional to the weight of the substances on which they act, in order to produce a definite effect, and Melloni has showed by his experiments with the thermo-pile that, taking the capacity of radiation for lamp black at 100, that of a metallic surface was only equal to 12. This inequality of the power of absorption for different bodies arises from their not having equal power of emission, for a surface which easily radiates heat must, conversely, also have the capacity for absorbing these rays. These considerations are most necessary to be borne in mind in connection with the important question of economy of fuel, and it may be said to be in no slight degree due to the neglect of them that the difference between the theoretic and effective value obtained from the combustion of coal is so conspicuously great. It will thus be readily seen that iron is not the best material to use in the construction of fireplaces, with a view to the economical use of fuel, its universal adoption for that purpose being due to its durability and the facility with which it is worked, rather than to its properties of conducting heat. Fire-brick possesses in a large degree those properties in which iron is deficient, but it lacks its strength and its convenience for working. In order, as far as possible, to combine the properties of each, the most simple method is to place a lining of fire-brick within the iron skin, and this plan, as will be presently shown, has already been generally adopted with very considerable success, by which the heat generated in the combustion chamber has been more effectively economised than could be accomplished without such a combination of materials.

The proper regulation of the supply of air to fuel is a subject of first importance in order to obtain the most perfect combustion, or, in other words, a certain quantity of oxygen, and no more, is required to consume the hydro-carbons and other vapours contained in coal. If the supply be too little, defective combustion will be proved by the emission of smoke; if too great, some of the gases will be carried off before they have had time to be properly burnt, and so a great portion of the

effective value of the fuel will be lost. Under varying circumstances fuel may be burnt quickly or slowly, as may be required; but it is important to bear in mind that a certain amount of fuel, if thoroughly consumed, gives out the same amount of heat under both conditions. If it be consumed in one minute, the heat emitted during this minute will be twice as much as it would be in the same time if the combustion were to last for two minutes, that is, provided in both cases the full theoretical value of the heat evolved during combustion be obtained. For steam purposes it would be obviously impossible to obtain sufficient results under a slow process of combustion, which, in other words, means a low temperature. "If any substance is consumed at a comparatively low "temperature, its heat will simply ascend, the heat-rays "so produced having little power of radiation or penetra-"tion, and the heat of the burning body going upwards "in the form of a narrow column of hot air. But as the "intensity of combustion is increased (in other words, "the hotter the flame) the radiating or penetrating power "of the heat-rays will be augmented, they will extend to "a greater distance laterally."* A thin fire will never be found attended with economical results, and for the following amongst other considerations: The oxygen contained in the air requires to be heated to a certain degree before it will enter into the chemical combination with fuel necessary for effecting perfect combustion; and in a thin fire much of the air will pass through the fuel without undergoing this necessary change, which could not be the case in a fire of proper proportionate thickness, as the air would then have to pass through a sufficient depth of incandescent fuel to ensure its proper chemical combustion and decomposition.

In common grate burning, the exactitude of the proper proportions of air to fuel is widely departed from. "At "one period we have a grate heaped with fresh fuel, "giving off half burned or wholly unburned gases; at "another, half exhausted coals coated with ash, to which "only a portion of the oxygen can obtain access. The "draught on the other hand is constant, or only oc-

* "First Report to the Board of Trade by the Gas Referees, &c." 22nd June, 1871.

" casionally varied. A stream of air driven through a " bed of ignited coals, first oxidises the lower layers, con- " verting the carbon it touches into carbonic acid. The " latter gas rising through the bed takes up more carbon, " becoming carbonic oxide, which is in part re-oxidised " again just above the coals, giving rise to flames. Unless " there is a large excess of oxygen, there is a proba- " bility that some of the combustible elements of the " gases will be unconsumed owing to imperfect inter- " mixture, and a rapid cooling below the point necessary " to insure ignition by the nearly exhausted oxygen. If " hydrogen be present in the form of hydro-carbon " vapours, it will by its stronger affinity, appropriate " oxygen to the exclusion of carbon, and even decompose " carbon already oxidised, the latter element passing off " in minute flakes, which constitute the dense black " smoke always abundantly developed where bituminous " or hydro-carbon fuels are burned in an insufficient " supply of air. In practice it is usual to drive through " the grate at least twice the quantity of air theoretically " necessary to oxidise the entire mass of fuel. The effect " upon the temperature is corresponding, as will appear " from the following simple estimates. If a pound of " bituminous coal were perfectly burned in a volume of air " just sufficient to oxidise all of the combustible elements, " the result would be as follows:—After deducting the " latent heat of vaporisation, there would be developed " about 13,000 units of heat. The resulting gases would " occupy (if their temperature were reduced to 60°) 146·6 " cubic feet, with an average specific heat of ·26. Their " temperature would therefore be $T=\frac{13,000}{11·23\times·26}\times 60°=4516°$; " provided no heat were lost by radiation. If twice the " volume of air were used, then $T=\frac{13,000}{22·44\times·24}\times 60°=2474°$, or " a little more than half the temperature under the first " supposition. Assuming the air to be 50 per cent. in " excess, then $T=\frac{13,000}{16·83\times·25}\times 60°=3150°$."*

It is generally held to be beneficial to admit a current of air above the burning fuel as well as below it, in order properly to aid combustion. This, if not attended with

* Paper read before the Franklin Institute, "On the use of Pulverised Fuel," by Lieutenant C. E. Dutton, U.S. Ordnance Corps.

suitable precautions, must have the initial effect of lowering the temperature above the fire, and so, in some slight measure, reducing the heat of the escaping vapours, and aiding in a reduction of the effective heat obtained from the combustion of the fuel when compared with its theoretic value. The advantages of the air current above the fuel may, however, be turned to full account in perfecting the combustion of escaping unconsumed vapours, and at the same time the reduction of heat which it causes may be neutralised by a judicious arrangement of two fire-places to one flue, so that their flames are directed towards each other, when the one will aid in consuming what is escaping from the other.

The emission of light from gas, or of heat from fuel, both depend primarily upon the attainment of a high degree of efficiency in combustion; and in investigating the principles required to ensure the greatest economy in the use of fuel, it may not be out of place to notice any particulars that may be available with reference to the burning of gas. In corroboration of the theory which has been above stated, the following quotation from a letter, appearing in a weekly Scientific Journal,* will be found to be very applicable:—" Having noticed, " what I am sure is familiar to many, that when two gas " flames are burned so as to impinge against each other, " and form one flame, there is a marked increase in the " light compared to what the two flames give when " burning separately, I made experiments to test the " increased amount of light from this method of burning " gas. On referring to my notes of these experiments, " I find that using fish-tail burners, when two No. 0 " burners were used, the light was nearly three times " greater when burned together than when burned sepa- " rately; with No. 2 burners it was twice greater, " while with No. 4 burners, it was scarcely one-third " greater."

In a previous chapter reference has been made to the necessity for protecting coal from exposure to the atmosphere, with a view to the preservation of its heat-producing properties. It now has to be shown that with

* " Engineering," November 17th, 1871, p. 330. Letter from Mr. John Aitken.

a view to the economical use of coal and other fuels in combustion, it is equally important that they should be kept under shelter, and protected as much as possible from absorbing moisture, for the freer the fuel is from water, the greater will be the effective value of the heat obtained from it when under combustion. All fuel contains hygroscopic water to a greater or less degree, which is driven out by the heat generated by combustion, and which heat is consequently lost for other purposes. The greater the amount of water contained in fuel, the greater will be the proportion of heat required to evaporate it, and consequently the less the effective power obtained. For all practical purposes, therefore, it may be asserted that water in fuel is conducive to a direct waste of heat, and should therefore be prevented. Wood, freshly felled, contains from 60·0 to about 18·0 per cent. of water, different kinds of timber having much more water in them than others, and "all kinds of wood, however well air-dried, retain on an average from 18 to 20 per cent. of water,"* on this account, therefore, a less proportion of the theoretic value of wood as a fuel is obtained than in the use of coal, as so much more of its heat is required to evaporate the hygroscopic water which it contains.

The question as to the use of wood or coal for fuel on the railways in India can be only one of time. The only reason now for employing wood on any of the lines is one of first cost, which in Southern India is very much in its favour, the relative cost per mile being on the Madras Railway as follows:—

	South West Line.			North West Line.		
	R.	A.	P.	R.	A.	P.
Coal and coke -	0	5	3.33	0	5	9.10
Wood - - - -	0	2	5.71	0	2	8.03

But then against this must be set the drawback of the greater weight and bulk of wood consumed, which is as follows:—

	South West Line. lbs. per mile.	North West Line. lbs. per mile.
Coal and coke -	23.41	25.30
Wood - - - -	77.38	83.40

On the other hand, the Reports of the Locomotive Super-

* Percy's "Metallurgy," v. I. p. 66.

intendent, Oudh and Rohilkhund Railway, show that on that line as much as 168lbs. of fuel were burnt, at a cost of 6.2 annas per train mile, and that the total cost of wood fuel per train mile during the six months ending 31st December, 1870, was no less than 9 annas 4·44 pie. At the then present rates, it was stated, coal from the Kurhurballee fields could be laid down on the Oudh and Rohilkhund Railway, at Cawnpore, for about £2 8*s.* 10*d.* per ton, and it would, therefore, appear that 53lbs. of coal might be consumed per mile, before wood fuel could compete with it at 9 annas 4½ pies per train mile. So large a consumption of wood fuel on the Oudh and Rohilkhund Railway may possibly have arisen from the timber having been felled before the trees were free from sap, or from its having been imperfectly dried, or improperly stacked after cutting. In Dr. Percy's work on "Metallurgy," it is stated that all wood when recently felled contains a large quantity of water, which varies in amount with the nature of the tree, the part of the tree, the season of the year at which it is felled, and, in trees of the same kind, with the place of their growth. When wood is exposed to the atmosphere during a sufficient length of time, under conditions favourable to desication, it loses the greater part of its water; but all kinds of wood, however well air-dried, retain on an average from eighteen to twenty per cent. of water. When wood which has been strongly dried by means of artificial heat is left exposed to the atmosphere, it re-absorbs about as much water as it contains in its air-dried state. The desication of wood by exposure to the atmosphere is much promoted by the removal of the bark, and the results of experiments made with a view to ascertain this circumstance showed that after the lapse of three months the barked wood was completely air-dried, whereas the unbarked wood had not even lost one per cent. Of the different parts of the same tree, the wood of the youngest branches contains about twice as much water as that of the trunk and older branches. According to Werneck the wood of trees which have grown on mountains, under the same conditions, is more compact than that grown in plains; the wood of closely grown trees is more compact than that of isolated trees; and the compactness appears to increase with the dryness of the soil.

"Although there is no means of estimating the *absolute*

" amount of heat" says Dr. Percy, " evolved by the com-
" bustion of a body, yet the *relative* amounts of heat " evolved by the combustion of different bodies may be " accurately determined. Rumford estimated the calorific " power of a body by the number of parts by weight of " water which one part by weight of the body would, on " perfect combustion, raise one degree in temperature. " Thus one part by weight of charcoal in combining with " $2\frac{2}{3}$ of oxygen to form carbonic acid will evolve heat " sufficient to raise the temperature of about 8,000 parts " by weight of water 1° C. Similarly, one part by weight " of hydrogen, in combining with eight parts by weight of " oxygen to form water, will raise 34,000 parts by weight " of water 1° C. The relative calorific powers, therefore, " of carbon and hydrogen are as 8:34."

From calculations given by Dr. Percy relative to fuel, in which it is assumed that the specific heat of carbonic acid and the vapour of water is constant at all temperatures, he shows that in respect to calorific intensity the value of fuel is, *cæteris paribus*, great in proportion to the carbon which it contains. " It is on this account that " charcoal, coke, and the highly carbonaceous coals of " South Wales may be so advantageously employed in the " smelting of iron, which requires a very high temperature. " The *combustibility*, however, of the charcoal or carbon- " aceous matter is an important element in this considera- " tion. Graphite is pure carbon, yet, owing to its extreme " incombustibility as compared with charcoal, its pyro- " metric effect would practically be very inferior to that " of charcoal. The longer the time required for the com- " bustion of any given fuel, the greater the loss of heat by " radiation and conduction, and, consequently, the less " the calorific intensity."

The following is a classification of fuels in the order of their value, the first on the list being that of least calorific power :—

Wood - - -		Soft. / Hard.	Products of carbonisation.	Wood—charcoal. / Peat—charcoal. / Coal—coke.
Peat.				
Coal	Lignite	Bituminous wood. / Brown coal.	Combustible gases - -	Carbonic oxide. / Hydrogen. / Hydro-carbons.
	Bituminous coal	Non-caking, rich in oxygen. / Caking. / Non-caking, rich in carbon.		
	Anthracite.			

In the Report to the Secretary of State for India on "Indian Railways," for 1870–71, it is stated that in the Madras Presidency alone it has been estimated that nearly 100 square miles of forest will be required to meet the demand for fuel for railways. How long the country would be able to meet the constantly increasing demand for fuel, if wood alone were obtainable, is a question which can hardly be expected ever to be seriously considered, for, with the extension of railways in India, it must be expected that the wood fuel of the country will speedily give place to coal; and if, at any time, the manufacture of iron should be successfully introduced into India, mineral fuel alone will be able to meet the demand that will then arise.

> "The yron mills are excellent for that;
> I have a patent draune to that effect;
> If they goe up, down goes the goodly trees.
> I'll make them search the earth to find new fire."*

Committee B of the recent Coal Commission state as follows in their report, with regard to the economy of coal in locomotives. "The report of Sir Daniel Gooch "was brought before the Committee in a letter from that "gentleman, to the effect that eight pounds per horse-"power per hour might be regarded as the result of the "burning of coal to produce steam in all cases in Great "Britain, and that good locomotives do not consume "more than three pounds per horse-power per hour. "Dr. Fairbairn remarks, 'With regard to the locomo-"'tives, I have a very strong opinion that we are not "'able to do much in the way of economy in that "'direction.' The saving, however, that has been lately "effected by the use of coal instead of coke is con-"siderable. As much power is now obtained from one "pound of coal as was got from one pound of coke, the "cost of the former being but little more than half that "of the latter. We have it in evidence notwithstanding "that, though the limits of economy are nearly reached "in the use of fuel in the locomotive, that on the South "Western Railway the substitution of coal for coke has "effected a saving of not less than £30,000 a-year. We "also learn that upon most railways the quantity of coal

* "The Costlie Whore." London, 1633. B. 4.

" used in the locomotive engines varies from thirty-eight " to forty-five pounds per mile, whereas by arrangements " introduced Mr. Joseph Beattie it has been reduced on the " railway of which he is engineer to twenty-five pounds per " mile." In further explanation of the above, it may be stated that twenty-five pounds per mile is the maximum allowed to engine-drivers, who receive a premium for any less consumption of coal per mile, and I am informed by Mr. Beattie that the consumption is often less than twenty-three pounds per mile.

Mr. Beattie's locomotive has a double fire grate, divided by a bridge running transversely across the fire box of the engine, and so arranged that the flame from the foremost fire is deflected on to the vapours of combustion arising from the other, or main fire place, by means of an arch constructed of fire-brick. On the 25th March, 1856, Mr. Benjamin Fothergill submitted a report to the South Western Railway Company on the performances of these engines, of which the following is an extract:—

" Now, if the London and South Western Railway Com-" pany have seventy engines in steam per day, and each " of them be fitted up for burning coal, and they are all " worked under similar circumstances to the 'Ironsides,' " there will be a daily saving to the Company of £80 10*s.*, " or £483 per week of six days, or £25,116 per annum. " These results, however, which are certainly extra-" ordinary, and can be fully substantiated, are partly " acquired by Mr. Beattie's patented arrangements for " heating the feed-water before it is pumped into the " boiler. . . . . Secondly, as to the capacity of coal engines " consuming their own* smoke, I have the pleasure to " report that Mr. Beattie's plans, referred to in connection " with the perforated fire-slabs, as introduced by him in " the fire-box of the 'Canute,' most perfectly effect that " much-desired object. The flame in the fire-box first " impinges on those slabs, and then passes through the per-" forations to the ordinary tubes in the boiler; of course " during the lighting of the fire there must necessarily " be an escape of some smoke, but as soon as the fire is " up, and the fire-slabs are sufficiently heated, the smoke

* This consumption of smoke is only another term for effecting superior combustion.

"entirely disappears, so that there can be no nuisance in "that respect on the journey, in the tunnels, or at the "stations."

Having thus briefly pointed out some of the leading principles to be observed with a view to ensuring economy in the use of coal as usually supplied for fuel, it remains to consider how the small coal, which is now to a great extent wasted, can be most economically brought into use, by which means the present coal resources of the world may be very considerably augmented. It has been the object, primarily, of the former part of this work to bring to notice the large amount of waste which now takes place during the several processes of manipulation through which coal passes between the colliery and the place of its ultimate destination, and the object of the author in writing this treatise will have been attained if it has the effect of directing public attention to this most serious national loss which is daily and hourly taking place.

The only practical methods that have hitherto been suggested for utilising small coal are two, viz.:—1. Burning it as a jet, by ejecting finely pulverised coal mixed with a proper proportion of air, into a suitable combustion chamber; and 2, Reforming it into blocks by one or other of the numerous processes that have from time to time been devised for the manufacture of what is commonly known as "Artificial" or "Patent Fuel."

An admirable account of the use of pulverised fuel has recently been published in the Journal of the Franklin Institute, by Lieutenant C. E. Dutton, U. S. Ordnance Corps, and it has been reprinted in "Engineering" for September and October, 1871. As, however, these papers may not in all cases be readily available, some brief particulars on the subject are now given. The generic idea involved in this process is not new, it having been the subject of numerous patents during the last forty years, but the defect which has hitherto rendered it a practical nullity for so long a time has been the want of a contrivance for pulverising coal with uniformity and cheapness. This has now apparently been overcome by a recent invention of Messrs. Whelpley and Storer, of Boston, who employ for that purpose a machine similar to an ordinary blowing fan, a description of which is thus

given by Lieutenant Dutton :—" The box is about " 18 inches in diameter, and about the same length. " Instead of opening at both ends, one end is tight round " the journal. The box is divided into two chambers by " a diaphragm, so that really we have two fans on the " same shaft, and their boxes communicate by a hole in the " diaphragm round the shaft. The fan at the closed end " of the box is in form and function a blowing fan. The " outer fan is the pulveriser. The coal is fed into the " open end of the pulverising chamber, is caught by the " swiftly revolving paddles, and reduced to powder, and " is then sucked by the fan through the diaphragm, " whence it is expelled by the ordinary tangential pipe " along with the blast. The coal is fed in the form of " coarse gravel; it is delivered as fine as flour."

The function of this machine is a double one. It pulverises the fuel and delivers it, along with the blast, into the combustion chamber, by a single operation. An 18-inch pulveriser reduces two hundred pounds of anthracite coal per hour, and it requires about 3½ horse-power to effect this. The same power reduces three hundred pounds of bituminous coal. A 42-inch pulveriser, requiring about 15 horse-power, will deliver one thousand to one thousand two hundred pounds of anthracite, or two thousand pounds of bituminous coal per hour. The paddles of the pulveriser are at their extreme ends in no case nearer to the walls of the cylindrical shell than half an inch. The most suitable velocity for every machine has been ascertained to be about 10,000 feet per minute for a point on the periphery of the paddle, which, for an 18-inch pulveriser, would be about 2,100 or 2,200 revolutions per minute. The feed of fuel must depend upon the effective duty to be obtained; if an inefficient quantity be introduced the required heat will not be obtained; whilst if, on the other hand, too much be introduced, the surplus fuel will only represent so much waste. The amount of air to be admitted must be sufficient to float the fuel, and no more. The function of the fire-grate in the use of pulverised fuel is far less important than when employed under ordinary circumstances, and it is consequently much reduced in size. It is employed, at first, to raise the temperature of the walls to redness around the coal tuyere, which is necessary, in order to ignite the dust as it enters the

furnace. Subsequently it is kept closed as tightly as possible, and the fuel within it serves merely to deoxidise the air, which filters through the doors, and to supply a small quantity of carbonic oxide. The small supply of inflammable gas materially assists and insures the speedy ignition of the coal dust. If an excess of air be supplied with the fuel then that excess represents a useless volume, through which the total heat must be distributed, with a consequent lowering of the temperature. If the air be deficient then the fuel will be imperfectly burned, becoming carbonic oxide instead of carbonic acid, and yielding much less heat, with about the same volume of gas, and a consequent lower temperature.

The best results in the use of pulverised fuel are stated to have been obtained with bituminous coal. In common grate burning, anthracite usually gives a more intense heat than soft coal, although its thermal equivalent is theoretically less. But in burning soft coal, the distillation of hydro-carbon vapours from the upper layers of the fire absorbs considerable heat, and as these are subsequently burned only very imperfectly, and with great loss by smoke, much of the thermal power of this coal is lost. In the reverberatory furnace the long flame of bituminous coal is required to fill the hearth, while anthracite would yield only an intense heat in the fire-place, and a flame short and of small intensity on the hearth. With pulverised fuel, the full, long, abundant flame, and the great temperature due to the higher thermal equivalent of bituminous coal, are both realised. Messrs. Whelpley and Storer claim that a very large economy is obtained by their process, in the expenditure of fuel in the operations of the reverberatory furnace. They state that in a practice extending over eight months, the use of the pulveriser attached to a double puddling furnace has given a general average consumption of one thousand two hundred and fifty pounds of coal to a ton of puddled bar. It is usual to estimate ordinary puddling at a ton of coal to the ton of iron, in which case pulverised fuel would give an economy of 45 per cent. of the amount at present used.

In a paper read before the Cleveland Institution of Engineers last year (1871), "On Methods of Producing "High Temperatures," by Mr. William H. Maw, a description is given of a method of burning pulverised coal,

invented by Mr. Thomas Russell Crampton, which had then been at work for some time at Woolwich Arsenal. In comparing the relative economy of using pulverised or ordinary coal Mr. Maw remarks as follows:—"As applied " to heating blooms, the Crampton system has given " excellent results, and a careful observation of four " weeks' ordinary working has shown an average con- " sumption of 5·66 cwt. of coal dust per ton of rolled " bars turned out, the maximum consumption during any " one week being 5·9 cwt., and the minimum 5·48 cwt. per " ton of bars. The waste of iron during the same period, " or the difference between the weight of the scrap charged " and that of the rolled bars produced, varied from but " 8·33 to 10·8 per cent., the average for the four weeks " being 9·2 per cent. These observations were taken at " a time when, from slackness of work, the furnace was " only worked eight shifts per week, and under these cir- " cumstances the quantity of rolled bars produced varied " from 42 tons 16 cwt. to 49 tons 6 cwt. per week, the " average for the four weeks being about 46½ tons per " week. The fuel used was coal slack, costing at the " works 9*s*. per ton, whereas in the ordinary furnaces on " the same establishment using large coal from the same " colliery, and costing 15*s*. 6*d*. per ton, the fuel used " amounted to 9 cwt. per ton of bars, and the waste of " iron averaged 11 per cent. With the coal-dust furnace, " also, the heats are got out much more quickly than with " furnaces of the ordinary kind, and the saving of labour " to the men in firing, &c., is something very considerable. " As I have already stated, a puddling furnace on Mr. " Crampton's plan has now been at work at Woolwich " Arsenal for some weeks; but the experience with it has " not yet been sufficiently extensive to enable detailed " data of its performance to be given. The results " hitherto obtained, however, have shown a consumption " of about 17 cwt. of coal dust per ton of puddled bars."

Some time back experiments were made by Mr. Crampton for burning powdered fuel in locomotives ; but they were not carried on to a sufficient extent to enable any definite conclusions to be arrived at. More recently he has been applying his system to a marine boiler, and has succeeded in evaporating as much as eleven pounds of water with one pound of fuel. *Theoretically*, a pound of pure coal should

evaporate between thirteen and fourteen pounds of water; but under ordinary circumstances, *practically* a pound of coal does not evaporate four pounds. It will thus be seen that Mr. Crampton can, by his process, obtain a much higher amount of duty out of coal than is usual under ordinary circumstances, and this result may be attributed entirely to the more perfect admixture of atmospheric air with the fuel, and which thus ensures its more perfect combustion. Committee B of the Coal Commission state—"Imperfect "combustion must be regarded as the first essential loss "(of the steam-producing power of coal). The air is "supplied so unskilfully that much passes into the chimney "as hot air, carrying with it the vast quantity of uncon-"sumed carbonaceous matter which we see escaping in "black clouds from the top of the chimney. This im-"perfect combustion may be traced to the bad construc-"tion of the fireplaces, and to the reckless way in which "coal is thrown into and over the mass of ignited matter "in the fireplace."

One circumstance worthy of notice, and which Mr. Crampton has observed in his recent experiments, is that when burning powdered fuel under a marine boiler, with a proper admixture of air, the heat in the smoke-box varied only from about 230 to 250 degrees, or but a little only in excess of the heat of the water in the boiler, whereas with the ordinary use of coal the smoke-box temperature will vary from 300 to as high as 1,100 degrees, or even more, showing that the combustion of fuel is taking place even up the chimney, and the heat thus generated is necessarily lost. On the other hand the equal and moderate heat in the smoke-box when powdered fuel is burned shows pretty conclusively that the process of combustion has been tolerably well perfected in the combustion chamber, and the large proportion of utilised heat is proved by the high rate of evaporative power shown to have been attained.

For manufacturing purposes, and even in some cases for stationary steam boilers, the use of powdered fuel may no doubt be employed with considerable economy. The special mechanical appliances at present considered necessary for its use, however, must limit its introduction, more especially abroad, and this process alone of utilising small coal must fall far short of being able to meet this

pressing question of the day, although it bids fair to assist greatly in the solution of the problem of how best to check the great national loss at present sustained by the waste of our small coal.

From the foregoing remarks on powdered fuel, it will be seen that special appliances are required for its use, and that the existing fireplaces would have in all cases to be altered to adapt them for the purpose. At the present, however, fuel in this shape must be looked upon as only passing through an experimental stage, it would hardly be considered desirable to make the necessary alterations in locomotive or other fireplaces to prepare them for it; nor, indeed, until this new process shall have been proved by more extensive employment to be really the success which its advocates claim for it. In the meanwhile some other method of utilising small coal must be looked for, and at present its manufacture into brickettes of artificial or patent fuel appears to be the most practical method of dealing with the question, and it will be seen that under certain conditions, and in many cases the use of patent fuel is likely to be superior to, and more convenient than any other application devised for a similar purpose.

The more perfect combustion of coal, when broken and made up into balls with clay, than when in its natural state was discovered so far back as 1670. A quaint description of how to make a fire by this method was published in a book at about that date, in which it was stated, "This "fire is durable, sweet, not offensive by reason of smoke "or cinder as other coal fires are, beautiful in shape, and "is not so costly as other fire, burns as well in a "chamber even as charcoal." Excepting when pitch or tar is used in large quantities, the above description holds good with regard to patent fuel as now manufactured. Balls made of small coal and clay are to be seen in the cottages of the peasantry in some parts of Wales at the present day; but, although it may answer their requirements for domestic purposes, such a description of fuel would be wholly inapplicable for steam purposes, amongst other reasons, on account of the large proportion of ash which it necessarily contains. It is now just seventy-three years since the first patent was taken out in this country for the manufacture of artificial fuel made from small coal

bound together by the use of other ingredients, and pressed into blocks. An immense number of patents have been filed between that and the present time, having the same object in view, and although amongst the list of patentees are to be found the names of men well known amongst scientific circles, it is surprising to find such an almost complete absence of any attempt to introduce a method of manufacture based upon scientific principles. It is not to be supposed that nature can be so far imitated as to effect the cohesion of particles of coal by any mixture which, upon drying or cooling, shall have the same properties as coal itself, but some nearer approach to nature may be found than in the use of the dung of animals, river sand, mud, clay, human excrements, or compound mixtures, the cost of which would be more than the value of the fuel itself when made. The essentials for patent fuel are that the binding medium shall contain as much carbon and as little smoke producing matter as may be possible; and it is most important to bear in mind that no chemical change is effected in coal used in making patent fuel. It has been supposed that by a free admixture of pitch or tar, a bituminous fuel might be manufactured from anthracite coal. There could be no greater mistake, for the fuel, however made, will always partake strongly of the nature of the coal from which it is made, the combination of it with other ingredients being purely mechanical and not chemical.

The fuels made in this country at the present day are principally "bituminous," that is to say, pitch or tar, mostly the latter, are used in their manufacture. A small quantity of fuel is made with fecula or starch, with a little pitch; and at one manufactory, at Britton Ferry, a silicious mixture is employed, very much upon the principle adopted in the manufacture of "Ransome's Patent Concrete Stone." Whether this last-mentioned process can be advantageously worked remains to be seen, but from the nature of its ingredients it may be not unreasonably anticipated that its constant use would prove detrimental to fire bars from the action of the silica upon the iron, and it may also be expected to form clinker in the fire, and so impede the free passage of air through the firebars, and lower the temperature of the fire. It is true that the ashes of coal are found to contain a large pro-

portion of silica, which proves the existence of that mineral in coal, but the amount required for effecting the adhesion of small coal into blocks must necessarily be out of all proportion to what a serviceable fuel should contain, and its presence in such quantities would not improbably, as has been pointed out, have injurious effects upon the fire-bars.

The principal manufacture of artificial fuel with tar, or where a mixture of pitch and tar is used, is carried on under the process known as Warlick's patent. Blocks made with this mixture have, before they can be used, to be subjected for some hours to heat in an oven in order to drive off the excess of hydro-carbons which has been introduced with the tar. The principle upon which tar is used is clearly as follows: Tar being semi-fluid readily mixes with the coal, and if agitated together sufficiently, each particle of coal will become coated round with a thin film of tar. During the process of baking this is reduced to pitch, and it is clearly much more equally diffused throughout the whole block than if it had been mixed with the coal in a dry, granulated state. In the manufacture of this fuel, each ton of small coal is mixed with twenty-two gallons (two hundred and forty-two pounds) of tar, or its equivalent in pitch, seven pounds of pitch being added for every eleven pounds of tar taken out. Thus, if all tar were used, the amount of binding matter added would be rather over ten per cent.; whereas, if only pitch, the proportion would be rather under seven per cent., but this process does not admit of the use of pitch alone; eighteen hundredweight of coal is put into a mixing machine, and the proper quantities of pitch and tar are thrown on to the top of it. After about three minutes, the mixture is let out at the bottom of the machine, whence it is conveyed away by screw worms to the presses, where it is formed into blocks. The blocks are piled upon trucks as they come out of the presses, and are carried away to the ovens to be baked. Here they are subjected to a heat of about 800° for nine or ten hours, during which time a charge of about nine tons of fuel throws off one hundred and twenty gallons of water and twenty gallons of oily matter. In the process of baking, the blocks lose on an average nearly five per cent. of their original weight.

Of pitch fuels, it will suffice to describe two different processes of manufacture. The main object to be attained

is, by the application of heat, so to soften the pitch that, when in the press, it shall spread as equally as possible, and in a thin continuous film throughout the whole mass. This may be effected either by the application of a dry, or a moist heat; according to Wylam's process the former plan is adopted, and the latter by Mezaline. Wylam's employment of dry heat may be applied in two ways :—According to the older process the small coal is passed through iron tubes placed in pairs side by side over furnaces, through which it is circulated, by means of screws running along their whole length, for about a quarter of an hour, in order to drive off the water. The coal is then conveyed, together with a proper proportion of pitch, into a hopper leading to a pair of rollers, and the coal and pitch are thus crushed together. A Jacob's ladder conducts the pulverised product into a mixing machine, which consists of a vertical cylinder having revolving arms within it, and surrounded by a jacket within which the flames of a fire circulate, heating the mixture as it passes through. It is then conveyed down a shoot to the presses, where it is formed into blocks. An improvement of the above process consists of passing the coal and pitch together into a hopper, in the proper proportions, by means of two elevators having different sized buckets. From the hopper the mixture passes through a Carr's disintegrator, in which it is thoroughly pulverised and incorporated together. It is then carried by another elevator into a hopper, whence it falls into a wrought iron cylinder placed on an incline within a closed furnace. This cylinder is made to revolve by suitable gearing at the rate of about three revolutions per minute, whilst a central bar having projecting knife blades, revolves within the cylinder at the rate of about fifty revolutions per minute. These blades are arranged as segments of a screw, and gradually work the mixture forward towards the lower end of the cylinder, where it is provided with an outfall. It is then raised again by an elevator to the head of a shoot, down which it falls into the moulding press. The amount of pitch used varies from seven to eight per cent. of the quantity of coal.

By Mezaline's process of manufacture, the small coal, together with about eight per cent. of pitch, is conveyed into a pug mill, in which it is further mixed, and superheated

steam is admitted through several orifices into the mass at different points, with a view to soften the pitch, and so make it unite better with the coal. The mixture then passes from the bottom of the mixing machine into an open circular basin, where it is agitated for a short time to allow some of the steam to escape, and to cool it a little before passing into the press. It will thus be seen that by this process a certain quantity of water is introduced into the fuel during manufacture, in the shape of steam, which is not subsequently driven off. Fuel made by this process, and subsequently exposed to a high temperature in an oven for ten hours, has lost as much as 3·98 per cent. in weight; thus showing clearly how large a proportion of water was retained in it.

A comparison of the quantity of pitch or tar added to the coal by any of the above processes, with the quantity contained in the coal itself, will show at once how unduly that ingredient is increased. Analysis of best steam coal from Abercarne shows that it contains 6·09 per cent. of tar only, whereas a larger proportion still is added for the manufacture of artificial fuel; thus more than doubling in quantity the bituminous matter in each ton of fuel as compared with the amount contained in a similar quantity of good coal. Notwithstanding this, however, experiments made with fuel composed of the small from good steam coal mixed with either pitch or tar, have generally shown it to be possessed of equally good, and in many instances superior powers for steam purposes, a given amount of fuel evaporating more water than an equal quantity of coal in its natural state, thereby proving it to be superior as a steam fuel; an explanation of the reasons for this will be presently considered. In making tests of this nature, however, it must be borne in mind that the only fair method is to test the fuel against the same kind of coal from the small of which it has been manufactured; for the manufacture of coal into artificial fuel can by no possible means improve the quality of the coal itself, but the superiority of the moulded fuel is due to the fact that in that shape it is placed on the fire under circumstances more favourable to good combustion in ordinary fireplaces, as at present constructed for boilers or otherwise, than coal in its natural state.

The earliest practical attempt to form coal into blocks

with a vegetable glue is apparently due to one Robert Rettie, who, in a patent taken out in June, 1846, proposed to make artificial fuel from "culm or dross coal, with a "solution of gluten, oxygenated or otherwise." The first fuel, however, of this nature, which was ever made in any quantities, was that invented by David Barker in 1864, who used as a binding medium a "farinaceous "matter made from fecula or starch, or potato farina." The manufacture of this fuel was at one time conducted on a small scale at Northfleet, on the Thames, and subsequently at Whitecroft, in Glamorganshire. From notes made during a visit to the Whitecroft works in January, 1869, the manufacture was then carried on in the following manner:—A mucilage was formed by the mixture of powdered potato farina with water, in the proportion of eight pounds of the former to thirty gallons of the latter, and to this from half-an-ounce to one ounce of carbolic acid was added. About eleven per cent. of this mucilage (from thirty to thirty-five gallons) was added to one ton of small coal, which then passed into a mixing machine, from which it was delivered direct to the presses, and formed into blocks, which were then baked in an oven at a temperature of about 300° for nine hours, in order to drive off the water, and harden the starch. This fuel had the advantage of freedom from smoke, but it was not hard enough to stand rough usage, nor would it bear exposure to the weather without injury.

The great objects to be obtained in order to render such a fuel serviceable were to waterproof it, and render it less friable. Several persons interested in this matter set themselves to work, and some of the first chemists of the day were consulted, but without success, until a chance experiment led to the discovery that by the addition of a certain proportion of powdered pitch to the mixed coal, the desired object was fully attained, whilst at the same time the fuel so made is neither smoky, nor offensive in smell, like the ordinary pitch-made fuels, but can be used, as indeed it is now largely used, for domestic purposes as well as for steam. This fuel has, of course, to be baked, in order that it may get rid of the water used in the starch with which it is made. This process is known as Lodge's Patent.

In considering the question of the manufacture of

artificial fuel in India, there does not admit of a doubt that the last named would be the best. Although potato farina is exclusively used in this country, it can equally well be made with flour from rice or other grains, rice being the best, as it makes the strongest glue. In carrying out experiments for the application of ground rice to this purpose, the great difficulty met with was how sufficiently to dissolve the rice without having to boil it for several hours. The first experiments were made with a high pressure boiler, in which the rice was boiled under a pressure of four hundred pounds to the square inch. This was effectual, but tedious. Ultimately an experiment was made to see what effect caustic soda would have. The result was instantaneous, the ground rice being immediately dissolved into a sort of gelatine, which was much strengthened by the addition of a very small quantity of alum dissolved in water. The same process is also applicable for other grains, and equally effective. Ten to twelve pounds of rice, or a rather larger quantity of grain less rich in starch, is sufficient for one ton of small coal. This should be boiled in ten to twelve gallons of water, a quarter of an ounce of caustic soda to each pound of grain having been first dissolved in the water, and one pound of alum dissolved in water added as soon as the rice shows, by its sudden thickening, and change from white to straw colour, that the necessary chemical change has been effected, and that it is thoroughly dissolved. It may then be mixed with the coal by any suitable machinery, and a proportion of pitch added, if it is likely to be exposed to the atmosphere, or to be subjected to rough usage, but in no case will it be necessary to add more than from 3 to 5 per cent. by weight of pitch, the amount being regulated according to the duty that the coal may be required to perform. With regard to the press for forming the blocks of fuel, the chief desideratum is that each block should receive an equal pressure of from one to two tons on the square inch. The greater the pressure, the more dense will be the fuel, but greater care must be taken in drying it. Fuel made under a pressure of one ton to the square inch may at once be placed in an oven of 250° to 300° temperature, but that subjected to the greater pressure should be first dried at a temperature not exceed-

ing 200°, and subsequently passed on to a higher temperature, or the consequences will be that the exterior will dry too rapidly, and the moisture from the interior, in forcing its way out, will split the block of fuel, and sometimes cause it to break in half. After having been dried at the lower temperature, they should then pass into the hotter oven in order partially to decompose the pitch, and cause it to fulfil its functions in rendering the block waterproof.

The above process of making artificial fuel cannot but commend itself as approaching nearer to the operations of Nature by the use of a combination of vegetable extract with bituminous matter as a binding material, than where pitch or tar only are employed; it also produces a decidedly better fuel, freer from smoke, and cleaner in the furnace. It is to be hoped, however, that as this branch of industry attracts a greater amount of attention, superior and more economical methods of accomplishing the same ends will be introduced. Finally, for the manufacture of the best fuel, the coal should be first washed, in order to remove, as far as possible, the shale and other impurities, the effect of which, when left in the coal, is only to increase the amount of ash in the fuel, and so to detract from its heat-producing powers.

CHAPTER VII.

Coal Washing.*

In most mining operations it has been the practice, from the earliest times of which we have record, to wash the minerals obtained from beneath the surface of the earth in water, before subjecting them to further purification by means of fire, for the purpose of separating a portion of the earthy matters, with which they are invariably mixed, from the ore. In former years this was accomplished in a very rude manner, which doubtless involved the loss of a not inconsiderable amount of pure ore. Dr. Percy, in his valuable work on Metallurgy, gives an historical notice of the mode of making iron in South Wales about the year 1750, in which it is stated as follows:—" On the wash or enclosed ground on the sides " of the hills, where we find oar, we dig a trench about " 4 or 5 foot wide, till we come down to the lowest vein, " about 14 foot deep, and in that depth is usually four " veins or layers of oar. Then we make small ponds to " hold rain water, or any that comes out of springs, above " the trench that is cut; and as fast as the ponds fill, we " let them down by a flood-gate into the trench, which " carries away all the loose earth, and leaves the myne " behind, and the lowest vein bare. They then under- " mine the banks of the trench on both sides, and when " great quantities of the banks are fallen down, they let " down the water out of the ponds again, which washes " away all the earth from the myne." Such then was the rude method of washing iron ore one hundred and twenty years ago; but although so primitive in method, the principle it will be recognised, was the same as that which prevails in ore-washing machines of the most approved

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* On " Coal Washing." By F. C. Danvers, Assoc. Inst. C.E., M.S.E. Reprinted from the " Quarterly Journal of Science," vol. 6, p. 487.

type at the present day, the separation of the ore from the earthy matters being due to gravitation. Thus, whilst the lighter particles were carried away by the water, the heavier and mineral portions were left behind.

Although coal washing has now been practised all over the Continent for about half a century, until comparatively quite recently the practice of washing the products of coal mines was unknown in this country, and for the following reasons. Coal, unlike almost every other mineral product, is found running in broad seams, varying from a few inches to many feet in thickness; and so great is the quantity in which it exists that the richer seams only are considered worth working at all, and from these blocks are obtained, possessing a very high degree of purity. Not many years back, it was the custom to leave all the small coal down at the bottom of the pit, or, if it was brought to the surface, it was either burned at the pit's mouth as so much worthless refuse, or run to spoil. Indeed, so wasteful has been the manner in which coal-mining operations have been carried on, that large quantities of valuable fuel have been lost, or habitually left at the bottom of the pit as not being worth raising to the surface. This subject was closely investigated in 1860, by Mr. Alexander Bassett, of Cardiff,* the result of whose inquiries showed that from thirty to forty per cent. of the products of mines is not unfrequently lost, owing to the imperfect method of coal "getting" usually adopted; but that where, either from the character of the seam of coal, or from the mode adopted in working, a less percentage of fuel is lost, "still, under the most improved "system, the quantity of small coal left in the mines, and "consequently for ever lost, bears a very large proportion "to that raised, and which could be brought to bank, if "a market were obtained for it."

Since attention was so forcibly called to the probable duration of our coal supplies by Sir William Armstrong at the meeting of the British Association at Newcastle in the year 1863, measures have been devised with the view of utilising that which was formerly counted as waste, and

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* "On the Large Proportion of Coal lost in Working." Paper read before the South Wales Institute of Engineers, in February, 1861, by Mr. Alexander Bassett, M.I.C.E.

the small coal is no longer permitted to lie unheeded at the bottom of the pit. In collecting the slack, however, in addition to any impurities which it contains as coal, such as shale, iron pyrites, &c., there will invariably be found mixed with it portions of rocky or earthy matters which have fallen from the roof of the heading during working, or which may be taken off from the floors of the passages whilst collecting the small coal for the purpose of sending it to the surface. Under these circumstances it is not to be wondered that the slack coal thus obtained contains a much greater amount of earthy impurities than does the coal from the same pit, hewn and sent to bank in larger or smaller blocks. As has been already stated, this slack coal from the pits was formerly considered to be worthless, or, at any rate, not of sufficient value to enable it to bear the cost of transport in order to bring it to market; recent experience has, however, shown, not only that such is not the case, but that what was formerly looked upon as so much refuse, may be readily separated from the impurities with which it is in a great measure mixed, and thus purified it obtains a ready sale either for cokeing purposes or for the manufacture of artificial fuel.

The general large yield of English coal beds may, no doubt, be assigned as the chief cause which formerly led to the adoption of an extravagant mode of working them, and this was further stimulated by an absence of machinery for the purpose, and a want of that knowledge on the subject which has in comparatively recent times been acquired and put into practice.

The inferior quality of a portion of the coal measures of France and Belgium, and, in the former country especially the comparatively small area over which they extend, led to the adoption of greater economy in working; and it is not therefore surprising to find that England is indebted to France for the introduction of the practice of coal washing, whereby the small and formerly unproductive yields of coal are now raised into an important branch of trade. Only a small portion of it is however brought into use in the manufacture of artificial fuel. That article is at present scarcely used in England, and the small quantity that is manufactured here is made almost exclusively for export. From the returns for

1867, it appears that the amount of artificial fuel exported during that year from the United Kingdom was only 150,051 tons, which may be taken to represent nearly the whole manufacture of it in this country. By recent improvements it is now possible to burn small coal in boiler furnaces, but by far the greatest portion of washed coal is converted into coke, for which purpose it is specially adapted, and at most large collieries in the country where bituminous coal exists there may now be seen a coal-washing machine and ranges of cokeing ovens as part of the indispensable plant of the colliery proprietor.

About sitxeen years ago a Mr. Morrison first introduced into this country a coal-washing machine from France, and having obtained certain concessions from some of the north-country coalowners, he proceeded to set the apparatus to work, and soon became celebrated for the superior quality of the coke manufactured by him. It was, however, some years before the principle of coal-washing became at all general, and for some time Mr. Morrison was the only person to carry it into practice. Gradually, however, the process was taken up, first by one, and then by another, until a washing machine has now become almost as necessary an adjunct to a colliery as a pumping engine.

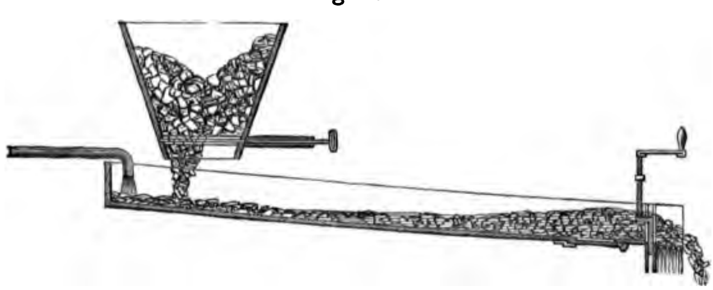
Very little alteration appears to have been hitherto made in the general principles of the first coal-washing machine introduced into this country, but alterations in detail have materially conduced to its greater efficiency and economy in working. As in the case of most other useful inventions, all sorts of modifications have been from time to time suggested, but few appear to have sufficiently recommended themselves on their own merits as to obtain any success. In all cases, excepting where only slack is washed, the coal has first to be broken up small, in order to prepare it for the washing machine. The means generally employed for separating the impurities from coal is gravitation, the mineral to be washed being thrown into water, when the earthy matters sink to the bottom, whilst the coal, being the lighter, forms an upper layer which is easily removed.

Numberless contrivances have been proposed for more readily effecting this disposition of strata in the washing machine, but, with the exception of those which we shall

presently notice, few have come into general adoption; and whilst many other plans have been projected for removing the impurities from coal, those in which water is employed, either in a running stream or in agitation, as will be presently described, alone appear to have been brought into practical use. In order to give a better understanding of how the last-named machines effect this separation, we shall first describe them more in detail, and then proceed to give some further particulars regarding the methods requisite to prevent any unnecessary waste of fuel; since, if care be not taken, much coal is liable to be carried away with the waste water, after it has passed through the machines.

The simplest, but by no means the most efficient, form of coal-washing machine is that consisting of a simple trough, or passage, having a smooth channel, and set on a slight incline in the direction of its length, as shown in the accompanying woodcut At the lower end, the trough

Fig. 1.



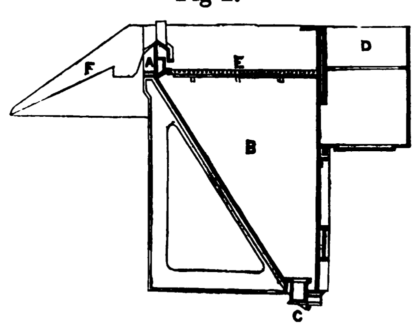
is fitted with a vertical sliding sluice valve, working up through the bottom, and in grooves in the sides, which may be elevated or depressed at pleasure by means of a screw; and just above this sluice is placed a valve, opening in the bottom or side of the trough. The mode of working is as follows. The coal to be washed is either first crushed by passing it between rollers, or, as is sometimes the case, the trough is placed under the screen, over which the coals are tipped in passing from the trucks, as they come from the pit, into the railway wagons. The finer particles of coal then, passing through the meshes of the screen, fall into the trough at its upper or more elevated extremity, into which also a continuous flow of water is admitted. The coal is thus carried down the channel by

the water, and it has to be kept constantly agitated during its passage, either by means of a long pronged fork worked by hand, or by a mechanical apparatus designed for the purpose. This agitation is necessary to ensure the more perfect separation of the coal from its impurities. As it flows down, the coal, being lighter than the shale or pyrites, rises to the top, whilst the heavier particles settle down and remain in the bottom of the trough. The coal then is permitted to pass over the sluice at the lower end of the shoot; but as the impurities accumulate, the sluice is gradually raised to prevent their passing away with the coal, and this is done until the sluice has been raised to a height nearly level with the top of the sides of the trough. The supply of coal is then temporarily turned off, and the valve opened in the bottom of the trough, through which the impurities are allowed to pass. The sluice is then lowered, and the same operation is repeated. In some machines of this type the trough is made very long, and a sluice is placed in the middle of its length as well as at the extremity. Attempts have also been made to dispense with the necessity for stirring the coal whilst being washed, by placing a series of projections across the bottom of the trough, which, acting as submerged weirs, were intended to give the water an undulatory motion; this, however, is not sufficient for the purpose, and experience has shown that a more sudden and violent action of the water is necessary in order to effectually separate the coal from its impurities. The objections to this form of coal-washing machine are that whilst it requires a larger supply of water for the purpose, the coal is not so thoroughly washed as in other machines; and that whilst the result is still only comparatively purified, a large amount of coal is probably wasted, by passing away with the other matters down the outlet valve before referred to.

The most generally adopted plan of coal-washing machine at present in use is a modification of a French machine, the invention of one M. Bèrard, and somewhat of the form of that first introduced into this country by Mr. Morrison. In this machine the coal, after passing between crushing rollers, is conveyed by means of a "Jacob's ladder" into a hopper, or shoot, down which it falls into small rectangular troughs, at the head of each of which a current

of water enters which carries the coal away, and deposits it on a wire, or perforated copper sieve. Beneath this sieve is a hopper-formed chamber filled with water in communication with the bottom of a cylinder in which a piston works at the rate of about one hundred strokes per minute. The motion of this piston agitates the water in the " bash," causing it alternately to rise and fall on the sieve. The coal on the sieve is thus kept in a constant state of motion being lifted up by the water as the piston descends, and falling again with its upward stroke. By this constant elevation and resettling, the heavier particles, which constitute the impurities in the coal, fall to the bottom and form the lowest stratum on the sieve; whilst the pure coal, after the space above the sieve is once full, is carried over the lip of the machine with the escaping water, and falls down a shoot into a truck placed there for the purpose of receiving it. As soon as any shale, or other impurity, is seen to pass over with the coal, or when the space over the sieve becomes filled with foreign matter (which may be readily ascertained by the attendant taking a small quantity out to examine it), the valve at A (see Fig. 2) is raised by means of a screw, or weighted lever,

Fig 2.



and the accumulated impurities are allowed to pass into the lower part B, from which they are subsequently removed by means of the valve C at the bottom of the machine. The piston works in the chamber D. It should have a stroke of not more than 2 to 2½ inches, and is usually driven at the rate of about one hundred strokes per minute. E is the sieve on which the coal rests, and after being washed it passes away over the shoot F. A

machine of this character, with pistons of 3 feet diameter, and "bashes" about 3 feet by 4 feet, will require a supply of about thirty-two gallons of water, per minute for each "bash" and is capable of washing about fifty tons of coal per day per "bash." A four "bash" machine, capable of purifying nearly two hundred tons of coal a-day, requires about a twelve horse-power steam engine to work it and the auxiliary machinery.

Having thus briefly explained the details of the washing machine itself, we pass on to notice the entire process through which the coal has to pass. The coal is brought direct from the pits in trucks, and emptied into the hopper sunk below the level of the ground. Thence, if the situation does not admit of putting a pair of crushing rollers into the first reception pit, it is carried by a Jacob's ladder, and thrown into a hopper, through which it passes to the crushing mill, to be broken up into a suitable size for washing, by which process also the attachment between the coal and its impurities is severed or loosened. After passing through the rollers it is lifted up into another hopper, whence it falls into a number of short shoots corresponding with the number of "bashes" in the machine, and a little above the point in the shoots where the coal enters, water is admitted through a service pipe, by means of which the coal is carried down on to the sieve, and the washing proceeds in the manner already explained.

According to one modification of this machine, which is in extensive use at Saarbruck, in Germany, a number of "bashes," instead of working separately, act together the washed coal from one "bash" falling over a small weir into the next, and so on until it has passed through the entire series. Although, no doubt, by this mode a much greater degree of purity is obtained in the washed coal, the plan of using the "bashes" separately, as practised in this country, is found to give results sufficiently satisfactory for all practical purposes; to continue the process further would, therefore, only be to incur additional expenditure without corresponding results.

Another modification of the above process ought not to be passed by without notice, for whilst it embodies most of the leading principles of Bèrard's machine, it has been

so adapted as to produce the greatest possible effect with the least practicable amount of water and the smallest expenditure of power. The modifications in this machine—which has been designed by Mr. Edwards—will be sufficiently well understood without an illustration, from the following description:—The coal and water are admitted together through a hopper on to the sieve, and instead of a piston, for keeping the water in the machine in a state of agitation, a float is placed so as to rest upon the surface of the water at a level below that of its height over the sieve. This float is attached to the top of the cistern, and the joint made water-tight by a leather flange, which admits of a certain amount of vertical movement by the float. The motion is given to the float by means of a three-throw cam; as the cam strikes the float, it is deflected, causing the water on the sieve to rise, in the same way as with the downward stroke of the piston in the machines already described. Indeed the float is in this case a piston working on the water, only without any cylinder to work in.

Directly the cam releases the float, the head of water forces it back, ready to receive the next stroke. Instead of making the water act as the means of conveying the washed coal from the machine, as in Bèrard's and most other modifications of that machine, a set of scrapers gradually carry it forward, and finally push it over the delivery end of the machine, and thus less water is required. The speed at which the motion shaft is driven need be but one-third that of Bèrard's, in order to obtain the same amount of work. One of Edwards's machines, capable of washing about fifty tons of coal per day, requires so little power to move it, that, were it not for the auxiliary crushing rollers, &c., which are generally indispensable with a coal-washing machine, it might be worked by manual power.

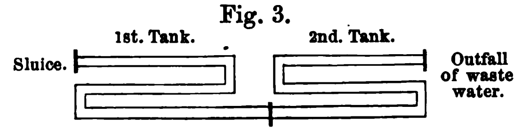
A very simple and inexpensive form of coal-washing machine may be improvised by placing a row of pipes in communication with a steam-pipe at one end, but closed at their other ends, and having a row of perforations along their length, at the bottom of a shallow box into which the water and coal fall. The upwards passage of steam through the pipes gives the water a sufficient amount of agitation to produce all the necessary effects obtained by the use of more elaborate machinery.

Most coal-washing machines are arranged so that the washed coal falls directly into a truck ready for removal to the cokeing ovens, to the artificial fuel manufactory, or any other destination. The coal thus caught forms, however, only a portion of what passes through the washing machine. It constitutes indeed the greater portion of it, and consists of all the larger pieces of coal, whilst many of the smaller particles and almost all the coal dust are carried away by the water as it flows off. In order to save this fine coal, which, it is found, contains the smallest amount of impurities, and is therefore best adapted for the manufacture of coke, it is necessary to form settling tanks through which all the water from the machine is made to pass. So much coal, however, escapes if due care be not taken, that it has in practice been found desirable to have at least three such tanks, each of which should be in duplicate, so that one set of tanks may be kept at work whilst the coal which has collected in the other set is being removed. Sometimes a fine mesh wire gauze, or finely perforated plate, is placed at the outlet of the first settling tank for the purpose of keeping back all pieces of coal above a certain size, but it is very doubtful whether such a precaution is necessary, as the larger pieces are sure to be deposited in the first tank, while the finest of all will be found at the bottom of the last settling tank. Even after all these precautions have been taken to save as much of the coal as possible, the author has witnessed instances where samples, collected promiscuously from the residue which escapes with the water after it has passed through the last settling tank, have been found to contain seventy-five per cent. of combustible matter, but it is certain that a small portion only of this consisted of pure carbon. Under a judicious arrangement of settling tanks it will be almost invariably found that the deposited coal becomes more pure in each successive tank up to the third, and that what is subsequently found to be held in suspension by the water contains too large a proportion of impurities to render it worth the trouble and expense of collecting.

Too much attention can hardly be given to the construction of settling tanks, whatever form of washing machine is employed, since, in the first place, the fine coal passing away with the water is the purest and best

adapted for the manufacture of coke, and secondly, unless this be carefully conserved the loss consequent upon the operation of washing may be such as to make it very questionable whether the cost is not out of all proportion to the benefits otherwise obtained. Even in a well-arranged coal-washing establishment the loss in weight by washing will often be found equal to from twelve to fifteen per cent., consisting of the impurities extracted, as well as a certain amount of small coal, which, as has been before explained, will always escape with the waste water. So far as the author's experience goes, there appears generally to exist at collieries a strong objection to devote a sufficient extent of ground to the proper construction of settling tanks. In setting them out care should be taken that the tanks are made only of such a width that they can be readily cleared out without the use of wheel-barrows; for this purpose they should not be more than 6 feet wide, and about 3 feet deep at the outside, and on either side of each tank trams should be laid, at a level somewhat below the surface, so that men may shovel the deposited coal directly into wagons. The tanks also should not consist of one long narrow trench each, as is most generally the case. For a large coal-washing establishment such an arrangement would be very inconvenient, and besides it would not be found to work so well nor to deposit so much coal as if each tank were made to consist of three or more rows of narrow trenches, communicating with each other at alternate ends, somewhat in the following manner.

Fig. 3.



Here it will be seen advantage is taken of the known tendency of any obstruction in the flow of water to cause it to deposit whatever matter it may hold in suspension. The total area of tanks required for any coal-washing works must depend upon the extent to which it is proposed to carry on such work, as well as in some measure upon the available amount of water for the purpose; it would, therefore, not be possible to lay down any general

rules upon that subject, which must be determined after a consideration of the special circumstances of each case.

The cost of washing coal varies very much at different collieries, but it may be assumed that, on an average, it should not exceed threepence or fourpence per ton. At some places the washing is done by contract, one man receiving a certain sum for each ton of coal washed, and providing all the labour necessary, and paying all expenses connected with the operation. At other establishments, the engine employed to drive the washing-machine may, perhaps, also be connected with other machinery, although it is better, in all cases that it should have an independent engine for its own use. Under such circumstances, the cost of working the engine would be borne by the proprietors, and the person contracting would, of course, not be entitled to receive so high a price as if he were responsible also for the whole duty of the engine.

The practice of coal-washing is, as we have already explained, a comparatively modern introduction in the economy of colliery management; but so rapid has been its extension within the last few years, that it is now coming into very general use. The advantages of thus purifying the slack of our coal mines are numerous, and calculated to benefit alike the producer and the consumer; for whilst it practically extends the available yield of our coal beds, it should have the effect of checking any inordinate increase of prices, if it do not actually tend to reduce the cost to the public at which certain classes of coal are now obtainable.

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